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OSTEOCHONDRITIS DISSECANS OF THE HEAD OF THE FEMUR

PARTIAL IDIOPATHIC ASEPTIC NECROSIS OF THE FEMORAL HEAD

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LOS ANGELES

Considering the large number of reported cases of osteochondritis dissecans of the knee joint and other large joints of the body, it is surprising how few observations have been made of the same condition in the hip joint. The English and American literature as far as I could find out does not include a single observation. I have been much interested in this peculiar lesion of the hip joint since my first observation of it in 1926 and have since collected 5 more cases of what is either osteochondritis dissecans or a condition closely related to it. There is no doubt that the disease is rare, and an exact diagnosis—as simple as it appears in outstanding cases—cannot always be made from a roentgenogram, representing, as it does, only one period of the lesion's development. Practically identical roentgen pictures may be presented by essentially different processes, so that the roentgenologic diagnosis of osteochondritis dissecans may not always be correct from a pathologic standpoint. It is still questionable whether even for the most common site of osteochondritis dissecans, the knee joint, different joint bodies have the same pathologic significance and whether such a body is always the result of a dissecting process which eliminates an area of primary aseptic necrosis from the living surroundings. The histologic picture of a joint body deriving from a supposedly typical process of osteochondritis dissecans is frequently so complex, as far as osseous structure is concerned, that the sequestration of a primary necrotic body can be ruled out even if at the time of surgical removal the entire body should show aseptic necrosis. Only a long-lasting process of reorganization of this area of epiphysial bone, with simultaneous or alternating periods of bone absorption and bone apposition, can explain the complicated osseous structure. Often it seems that a rather advanced, even accomplished stage of revitalization has become interrupted or annihilated by a secondary trauma, which may cause complete aseptic necrosis.

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Such a body should not be likened to a sequestrum caused by osteomyelitis or tuberculosis. The pathologic process from which it originates is in many instances more complicated; there seems to be a more intrinsic disturbance than simple dissection of a necrotic piece of bone. Occasionally a careful roentgenologic follow-up over a long period leads to pictures which are incompatible with the diagnosis of osteochondritis dissecans in the sense Koenig's term has received through Axhausen's investigations, although the final picture may have all the characteristic appearances of such a lesion.

I have searched the literature for observations of osteochondritis dissecans of the hip joint and have collected the following reports. Most of them are clinical and roentgenologic reports. Few authors have reported more than a single case, which indicates the rarity of the condition. The German and French literatures present the most contributions. Owing to external reasons, my review of the literature is not complete. It seems however, to cover all the essential facts and symptoms associated with osteochondritis dissecans of the hip joint, so that I can here present a rather complete pathologic and clinical picture of this rare condition, based on the reports in the literature and on my own observations.

The following cases have been collected from the literature. The first 2 were observed by Lange [1] in 1929.

A 17 year old youth complained of increasing pain in the region of the right hip for three months. Roentgenograms revealed a typical picture of osteochondritis dissecans in the lateral quadrant of each femoral head. There were also some anomalies of ossification in the spinal column and in the left tibial tubercle.

A 22 year old man had pain in the left hip joint, gradually increasing during the last six years. Roentgenograms revealed a typical picture of osteochondritis dissecans in the left femoral head. The right hip seemed to be normal. Examination eight years later showed that the patient was practically without complaints; he walked for about two hours without difficulty but could not do more. The right hip was without subjective symptoms. A roentgenogram of the left hip showed that substitution of the necrotic subchondral area had occurred, with firm union. The osseous structure was irregular, denser areas alternating with more porotic ones. The joint surface was uneven. The joint space was narrowed, and beginning hypertrophic arthritic changes were present. A roentgenogram of the right hip showed the typical picture of osteochondritis dissecans in the upper quadrant of the head of the femur.

Lange mentioned that the first case was also observed by Haenisch in 1925.

A 24 year old man had been perfectly well up to two months before observation by Bergmann [2] in 1929. Without trauma, there was an acute onset of pain in the left knee joint, gradually increasing and finally localizing in the left hip.

1. Lange, M.: Ztschr. f. orthop. Chir. **51**:269, 1929.
2. Bergmann, E.: Deutsche Ztschr. f. Chir. **217**:400, 1929.

Physical therapy produced no improvement. The lower part of the left extremity was kept in flexion, abduction and external rotation, and there was marked restriction of motion. All attempts at motion were painful, especially weight bearing. There was a decided limp.

A roentgenogram revealed a free calcified joint body with a sharply outlined bed in the head of the femur. There were no other signs of pathologic change. There was good configuration of the femoral head.

Operation was performed, with removal of a cartilaginous bony body the size of a peach stone. The body derived from the foveal region and still had a portion of the ligamentum teres attached.

The patient made a complete recovery. Normal motion of the hip joint was present eight weeks after the operation.

The histologic picture was that of aseptic necrosis of bone. The cartilage on the surface was alive to the greatest extent. The subchondral bone marrow was active, and there was enchondral ossification of the cartilage. Further down, the bone marrow and the spongy bone were alive, and the latter had a mosaic structure. The lower surface of the body, where the separation took place, showed necrotic old lamellar bone tissue.

Bergmann concluded from the activity of bone resorption and bone apposition that the process was of much longer duration than the clinical history would suggest.

A 16 year old boy had pain in the region of the left knee for six months before he was examined by Gold [3] in 1930. Physical examination showed the patient to be well built and in good general condition. The left hip showed slight limitation of abduction and hyperextension. The roentgenograms showed a subchondral segment in the cranial epiphysial pole, separated by a narrow zone of osteoporosis. The bony structure of the body was slightly cloudy with some osteosclerosis in the neighborhood. The same picture was presented by the right hip joint.

Gold observed the case for two years. Roentgenologically there was slow progress in both hip joints. The right side remained free from clinical symptoms.

Gold [3] also reported the case of a 13 year old boy who complained of pain in the left hip joint for one and one-half years. The roentgenograms showed a troughlike decalcification of the upper pole of the head of the left femur, with definite condensation at the floor of the apparent depression. Within the troughlike subchondral area was a small isolated bony focus of decreased density. The joint space was of normal width. Nine months later the head was in reconstruction; the troughlike impression was shallower, its bony structure spotty and the bony outline of the head in reappearance; the sclerotic zone of demarcation was narrower and darker. Four years later there were normal clinical and roentgenologic findings.

A 26 year old man had had pain in the left hip joint for four years preceding examination by Goldau.[4] The onset was gradual. No trauma had occurred. The pain rapidly became unbearable. On clinical examination the motion of the hip joint was free but painful. There was no muscle atrophy and only a slight limp. The roentgenogram showed an elliptic fragment in the upper pole of the head of the femur. The right hip was normal. A plaster cast was applied for six months, with some relief. Five weeks after the cast was removed the pain

3. Gold, E.: Deutsche Ztschr. f. Chir. **225**:296, 1930.
4. Goldau, D.: J. de radiol. et d'électrol. **15**:567, 1931.

was just the same as before. The patient was considered a malingerer and under the pretext of an arthrotomy only the skin was incised. There was no improvement.

An interesting case has been reported by Stören.[5]

The patient was a 27 year old man. At the age of 10, without trauma, pain appeared in the left knee, but only on motion. At the age of 14 there was swelling in the finger joints. Two months previous to admission there was a sudden onset of pain in the right knee, with articular effusion. The joints never locked. On physical examination the patient was found to be well developed, but the lower extremities when compared with the upper part of the body appeared a little thin. There was a limp to the right. A roentgenogram of the right hip joint showed at the weight-bearing portion of the femoral head a 1 to 3 cm. cavity filled by a sclerotic body which was separated from the other epiphysis. Below the mousebed there was a cystic area of osteoporosis about the size of a pea. A roentgenogram of the left hip joint showed that the head of the femur was smaller and the joint space narrowed. At the weight-bearing area there was a deep defect in the joint surface, of the size of a Spanish nut, with sclerosed wall. The right knee joint showed a cavity 2 cm. wide in the central portion of the joint surface of the inner condyle. In the cavity there was an irregular sclerotic body. The lateral condyle showed a small bony body close to the joint surface. The medial condyle of the left knee joint revealed an area of osteoporosis the size of a bean in the joint surface, surrounded by osteosclerosis. Examination of the hands showed separation of the ulnar portion of the head of the first phalanx of the little finger on each hand as in osteochondritis dissecans. The phalanges of the outer fingers were shorter than those of the inner ones. Some of the finger joints were uneven as in arthritis deformans.

Operation was performed, with removal of a free body from the right knee joint. There was a typical osteochondritis bed in the inner condyle. Another cartilaginous-bony body, measuring 2.5 by 1.5 by 1 cm., was observed in the lateral condyle. The patient made a good recovery.

It is interesting to note that similar articular lesions were found in other members of the family. There were ten brothers and sisters. The oldest brother had had a limp since he started to walk (he probably had congenital dislocation of the hip joints), but at the age of 14 he clinically had an articular condition similar to that of Goldau's patient.[4] Another brother at the age of 10 had the same trouble in the hips. He was operated on in America for a free joint body in the knee joint. A sister had similar trouble in the hip and knee joints; clinical symptoms started relatively late, at the age 30. The other brothers and sisters were normal. The father was 60 years of age; at the age of 7 or 8, without pain or swelling, his right hip and ankle and wrist joints became stiff. He was unable to move around and had to sit in a wheel chair until the age of 10 or 11. Then the stiffness gradually subsided, and at the age of 14 he became apprentice to a tailor. There was a steady improvement, and at the age of 30 he was so well that no one could notice any disability, but there was almost always some pain in the right ankle; later the right wrist joint became stiff but was not painful. At the age of 50 there was pain in the left hip joint, with limitation of motion. On physical examination (roentgenograms were not taken) adduction-flexion contracture of both hip joints was found, with marked limitation of motion. In most of the other joints there were arthritic changes with crepitation but no

5. Stören, H.: Acta chir. Scandinav. **74**:491, 1934.

pain. The hands showed the same deformities as did those of his son, the patient in the present case. The fingers were short and clumsy, with abnormally short distal phalanges. There was radial deviation in the middle joint of the little fingers.

Stören concluded that there was a multiple joint lesion in the sense of osteochondritis dissecans which existed in the father and four children. Osteochondritis dissecans develops on the basis of a primary constitutional and hereditary abnormal condition or lesion. That it is so frequently isolated, occurring only in one joint, might be explained with the assumption that the primary lesion remains latent. Trauma is usually absent in the history.

Stören also mentioned 2 cases in which the condition was treated surgically and reported by Moulonguet in 1932.

A 48 year old man complained of pain in the right hip and an increasing limp during the last year before he was examined by Mouchet [6] in 1935. The gait was good for several months, but there was vague pain, first in the region of the knee joint, then in the hip. On physical examination, right hip in adduction, atrophy of the right lower extremity was noted. Abduction and external rotation were almost nil; flexion was good. Internal rotation and circumduction were very limited. Tenderness was present over the head of the femur. The left hip (of which the patient never complained) had considerable limitation of abduction and slight limitation of external rotation. A roentgenogram of the right hip showed a large portion of the bony epiphysis separated by a semicircular zone of osteoporosis. The entire head was flattened and slightly pushed into the acetabulum. The left hip joint was roentgenologically normal, but clinically Mouchet suspected the beginning of the same trouble.

I shall now present my own observations and shall discuss each one individually with its specific problems. A final summarizing comment will stress the common features. My observations, with the exception of the last, have been reported in different German and American journals.

Case 1.—A 5 year old boy was observed [7] at the Istituto Ortopedico Rizzoli, Bologna, Italy. The child was always in good health. Six weeks before admission trauma to the right hip joint had occurred, and since then the parents had noticed a limp. On physical examination the boy appeared in good health. There was some atrophy of the right thigh, with tenderness over the right hip joint. Motion of the right hip joint was limited in abduction and rotation but was perfectly free on the left side. The roentgenogram showed a typical picture of rather advanced Perthes' disease of the right hip. An unusual picture was presented by the left hip joint. The joint surface was uneven and wavy, with an irregular subchondral area of osteoporosis. Otherwise the joint ends and the joint space were normal. The right hip was immobilized in a long hip spica cast. No special attention was paid to the left hip, which was left free. Frequent roentgen examinations were made. The reorganization of the right femoral head took a satisfactory course.

6. Mouchet, A.: Presse méd. **43**:1483, 1935.
7. Freund, E.: Arch. f. orthop. u. Unfall-Chir. **30**:57, 1931.

The osteoporotic changes in the head of the left femur first advanced slightly, then followed new bone formation without noticeable deformity of the weight-bearing joint surface.

The reorganization of the right femoral head was so well advanced after a period of two years that free weight bearing was permitted. The child had never complained of pain or stiffness in the left hip joint. The roentgenologic changes were merely an accidental finding during the treatment of Perthes' disease of the right hip.

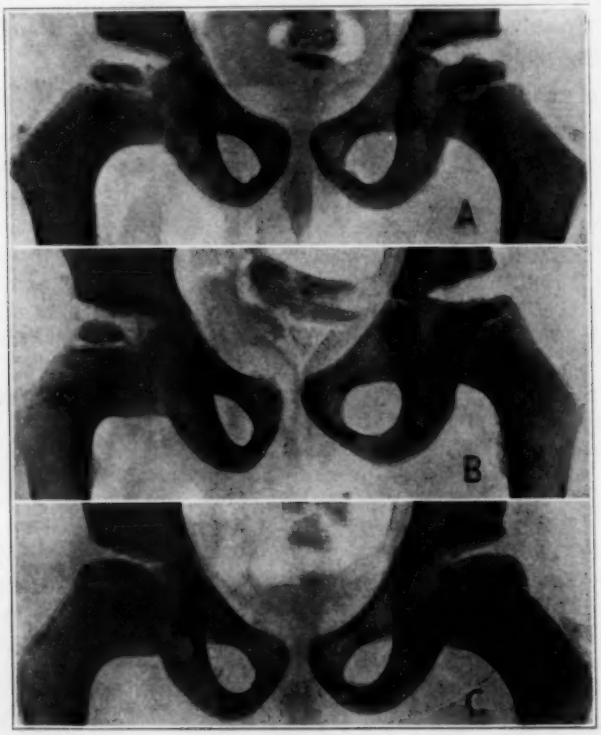

Fig. 1 (case 1).—Anteroposterior view of the pelvis, taken at different periods. *A*, typical Perthes' disease of the right femur in the stage of fragmentation. This roentgenogram was taken in May 1927. Note the irregular focus of osteoporosis in the subchondral zone of the left femur. *B*, advanced reorganization of the right femur. Note the increase in osteoporosis in the left femur, with an apparent defect of the weight-bearing portion and widening of the joint space (March 1928). *C*, complete reconstruction of the right femur, with a good anatomic result. The pathologic picture of osteochondritis dissecans was observed in the left femoral head after reconstruction of the subchondral area (June 1930).

One and a half years after the boy was discharged from the hospital he returned, stating that for some time there was a little pain in the region of the left hip, with slight limitation of motion; the right hip had never bothered him since the last hip spica had been taken off.

The roentgenogram revealed a characteristic picture. Corresponding to the previously observed subchondral area of osteoporosis, a rather large lentil-shaped porotic body was present, extending over practically the entire weight-bearing portion, separated from the other normal portion of the epiphysis by a narrow translucent zone of osteoporosis. The whole epiphysis was low, but its joint surface was even when compared with the other side. There was no difference in shape. This was remarkable when one considers that the right hip suffered from Perthes' disease. A short hip spica cast was applied to the left leg for three months. After its removal there was no pain in the hip, which moved almost freely.

This case is of considerable interest. There is no doubt that, seeing only the last roentgenogram and not knowing anything about the history and previous roentgenograms, one would make the diagnosis of osteochondritis dissecans of the left hip joint because of the fact that a lentil-shaped subchondral area, sharply outlined toward the joint cavity, was separated from the other, slightly denser portion of the epiphysis by a distinct dissecting zone of osteoporosis. However, knowing the development of this subchondral area, one can quite safely rule out true osteochondritis dissecans despite the fact that the last roentgenogram appears to be fairly typical of such a condition. Osteochondritis dissecans, according to Axhausen's generally accepted conception, is the separation of a more or less wedge-shaped subchondral area of aseptic necrosis. The roentgenologic expression of this process of demarcation is the appearance of a narrow porotic zone which surrounds the necrotic area of normal or increased osseous density. The roentgenologic shadow may become "loosened up" once the reorganizing fibrous bone marrow has invaded the necrotic body.

If this is the meaning of the term "osteochondritis dissecans," such a condition cannot exist in a case in which from a roentgenologic point of view the first and safest sign—the zone of demarcation—appeared many years after the onset of the epiphysial changes. It became visible after new osseous tissue had formed in the affected subchondral area where only bone resorption took place at first. *It was not that a primary necrotic subchondral area of old spongy bone underwent dissection, but that a reorganized portion of the epiphysis with new spongiosa did not find consolidation with its surroundings.* The linear zone of osteoporosis, therefore, cannot be considered as a zone of demarcation; it is rather a zone of pseudoarthrosis which probably formed under the influence of mechanical irritation of the subchondral area during the process of reorganization.

It is probable that while the right femur showed complete necrosis of the upper part of the epiphysis under the picture of Perthes' disease, the left femoral head was only partially affected, evidently only the subchondral area of the weight-bearing portion becoming necrotic. It is peculiar, however, that (to judge from the roentgenograms) revitaliza-

tion started immediately under the joint cartilage and gradually descended. As a rule, one expects progress in the other direction. The reorganizing bone marrow invades the necrotic area in a centrifugal direction; the marrow spaces below the joint cartilage are reached last. It may be that in this case the direction was reversed because the new bone marrow derived from the connective tissue and vessels of the ligamentum teres and not from the marrow spaces. Inasmuch as the bone-absorbing process of reorganization takes place in the centripetal direction, it is clear that the first foci of new bone formation will appear immediately under the joint cartilage, where the old necrotic bone has been removed first, and it is further clear that the new osseous foci will be surrounded at their under surfaces by the fibrous bone marrow in which they develop and which is still maintaining the process of revitalization. The whole process takes place under almost normal use of the joint, possibly even under overuse because of the protracted immobilization of the right hip in a plaster of paris cast. Intermittent weight bearing must lead to a more or less springlike up and down motion of the upper epiphysial pole, which has been deprived of its solid connection with the rest of the epiphysis. The new osseous tissue, reunited with the joint cartilage, is pressed into the underlying fibrous tissue, which under this rhythmic irritation by pressure gradually presents the symptoms of pseudoarthrosis.

It should be emphasized that it is merely by chance that physicians have the possibility of definitely ruling out osteochondritis dissecans. The earliest change in the left hip, in the case just described, would never have been detected if it had not been for the condition of the right hip joint, which was affected by Perthes' disease. There were no subjective symptoms or objective clinical findings which would have indicated taking a roentgenogram of the left hip joint. Pain and subjectively noticed limitation of motion of the left hip (some restriction of flexion and rotation had been found temporarily on previous occasions) did not appear until three years after the first observation. (The right hip joint had, meanwhile, completely reorganized, with an excellent anatomic and functional result.) This means that clinical indication for taking a roentgenogram of the left hip joint did not exist before the entire process in the epiphysis—from a pathologic standpoint—had come to a standstill and had assumed in its healing stage the picture of osteochondritis dissecans.

This is very important, because by these accidental findings a new light is thrown on the problem of osteochondritis dissecans. It is possible that a patient with an apparently typical roentgen picture of osteochondritis dissecans and with subjective symptoms of short duration has had pathologic changes in the epiphysis for many years. Such epiphysial changes may decidedly suggest osteochondritis dissecans by their roent-

genologic appearance and may still not be those of a simple process of dissection and sequestration. This fact may explain why in so many cases osteochondritis dissecans often has such surprisingly long clinical duration; the condition is frequently present for many years without either the formation of a free body or complete reorganization. It is likely that in such cases the condition is not dissection or revitalization of an area of aseptic necrosis. Both processes—dissection or substitution—should be terminated sooner if one considers the relatively short period of two to three years it takes to reorganize completely the entire head of the femur in cases of Perthes' disease. It is, rather, a living, subchondral portion of the epiphysis, resulting from reorganization of aseptic necrosis, which has never become reunited with the rest of the epiphysis. I feel that in such cases the term "pseudo–osteochondritis dissecans" is more appropriate than "osteochondritis dissecans." It seems that a number of cases reported in the literature belong to this group, certainly the second case of Gold, in which "dissection" never occurred but in which the patient made a complete recovery with restitution of the shape and structure of the femoral head. Lange's cases are also suggestive of pseudo–osteochondritis dissecans because of the osteoporotic shadow of the dissected bodies. A true osteochondritic body has either normal or increased osseous density. The dissection prevents all porotic changes which could take place on the necrotic spongiosa. Osteoporosis is always a sign of vascularization of bone marrow. If a subchondral body has a lighter shadow than the normal surrounding bone, it must have a blood supply and cannot be necrotic. If it is not necrotic it is not a true osteochondritic body.

There is another question to be answered. If Gold's second case and my observation represent essentially the same type of pathologic process, why did the condition in Gold's patient progress to complete cure and the condition in mine to nonunion? The answer probably lies in the fact of immobilization. Gold employed immobilization for seven months, apparently a sufficient period to establish good consolidation and perfect reorganization. My patient was permitted to use and possibly even to overuse the left leg during the period of most active structural changes in the femoral head. This difference in treatment may account for the different outcome. Rigid immobilization appears natural in cases of bone grafting to bridge joints or fractures; and essentially the taking of a bone graft is nothing but a process of reorganization of aseptic necrosis of bone. I was able to demonstrate in 1931 that early, adequate, protracted immobilization gives better results in cases of Perthes' disease than late immobilization or none at all. If it were not for secondary, complicating traumatic factors occurring during the active stage of reorganization, aseptic necrosis of bone should always heal with complete restitution. To avoid secondary trauma, immobilization is of

greatest importance. It is the treatment of choice if only the correct diagnosis of aseptic necrosis could be made on time. The latter, however, will remain a pium desiderium. Clinical symptoms are usually expressive of late complications, of deformity or of direct articular involvement. Roentgenologic recognition of aseptic necrosis of bone is possible only when reactive changes, either osteoporotic or sclerotic, have taken place in the living tissues in the region which also indicate a late stage of the disease. One seldom is able, therefore, to observe a case of correctly diagnosed idiopathic aseptic necrosis of bone in an early stage and a complete restitution of form and structure, to be expected a priori, will thus unfortunately never take place.

CASE 2.—A 15 year old boy was observed[8] at the Istituto Ortopedico Rizzoli. A limp appeared at the age of 13, immediately after the boy had had diphtheria. The pain was mild except after walking for a great distance. For the last few months the limp had been more marked, but the pain remained mild.

On physical examination the boy was observed to be decidedly hypoplastic. His body resembled that of a boy of 11. There was a strong disproportion between the length of the trunk and that of the extremities, in favor of the latter. In upright position the pelvis was inclined to the left. The right lower extremity was kept slightly abducted and externally rotated. The knee was slightly flexed. The left leg was adducted. There was convex lumbar lordosis on the left side. There was a decided limp, with a list of the trunk to the right. The Trendelenburg sign was absent. The extremities were of even length. The right hip joint showed slight abduction contracture; there was no adduction or external rotation. No pain or tenderness was present. The left hip joint had free motion. A clinical diagnosis of Perthes' disease of the right hip joint was made.

Roentgen examination showed both femoral epiphyses to be symmetric. The upper pole of each was porotic. It was separated from the other, normal portion of the epiphysis by a zone of osteosclerosis which was widest in the middle and thinner toward the joint surface. The subchondral focus of osteoporosis was a little larger in the left femur, where the zone of osteosclerosis was also much stronger and reached down to the epiphysial plate. The capital epiphyses were low and slightly flattened over the porotic area. The joint space was somewhat widened. The bony structure of the subchondral area in the right hip was different from that in the left. The spongiosa was still connected with the joint cartilage in the right femur; it was denser than the portion close to the sclerotic zone of demarcation. In the left femoral head there was more fanlike dissolution of the focus, with rather regular alternation of markedly porotic with less porotic strips.

The condition in this case was apparently intimately related to "pseudo–osteochondritis dissecans" inasmuch as a porotic subchondral portion, evidently in the middle of an active process of reorganization, was separated by a distinct zone of demarcation from the rest of the epiphysis. In this instance, however, it was not a separation by dissection; the subchondral focus was surrounded not by a zone of porosis but by marked osteosclerosis.

8. Freund, E.: Fortschr. a. d. Geb. d. Röntgenstrahlen **41**:935, 1930.

Exactly the same type of case with the same roentgen picture has been described by Kreuz [9] as "unusual changes in the upper femoral epiphysis." Kreuz's patient was a 9 year old girl who for two years limped and kept the right leg in external rotation. Clinically, as in my case, the diagnosis of Perthes' disease was made, but roentgenologically there was a troughlike defect in the upper pole of the epiphysis, separated from the normal portions of the epiphysis by a strong band of osteosclerosis.

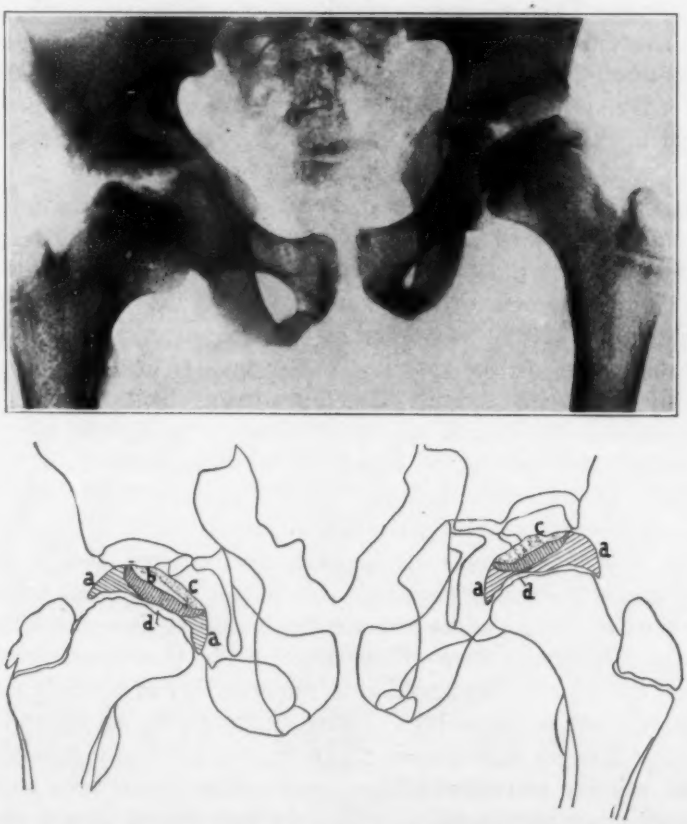

Fig. 2 (case 2).—Anteroposterior view of the pelvis, with corresponding sketch. There is a peculiar lesion of both hip joints, resembling osteochondritis dissecans: *a*, normal portion of the epiphysis; *b*, complete absorption; *c*, marked osteoporosis in the subchondral area, which is surrounded by a zone of osteosclerosis *d*.

Kreuz correctly ruled out Perthes' disease because there never was a case of Perthes' disease starting from a circumscribed focus of osteoporosis within the capital epiphysis. He also rejected osteochondritis

9. Kreuz, L.: Fortschr. a. d. Geb. d. Röntgenstrahlen **40**:1034, 1929.

dissecans, because during the whole time of observation there was no shadow of a sequestrated osseous body; on the contrary, it seemed that the subchondral focus of osteoporosis enlarged during the period of observation. He considered his case as a special form in the group of osteochondropathies.

Although it is true that in Kreuz's case and in mine the conditions observed were neither Perthes' disease nor osteochondritis dissecans they were closely related to both. There is no essential difference among these forms. They all are primarily aseptic necrosis of the femoral head. The differences derive from the extension of necrosis and from the later complications of the process of reorganization. In Perthes' disease it is the entire bony epiphysis which becomes necrotic; in Kreuz's case and in mine, and in true cases of osteochondritis dissecans, it is only the subchondral portion of the epiphysis.

It is the degree of involvement of the epiphysis which differentiates these conditions from Perthes' disease; it is the difference in the process of reorganization which separates them from true osteochondritis dissecans. There are essentially two courses the process of reorganization may follow in a case of aseptic necrosis: reorganization in the form of slow substitution of the necrotic tissue by living bone marrow or demarcation (sequestration). The latter, as I shall point out, seems always to be a late complication; it follows a process of substitution at a rather advanced stage, especially if reorganization is hindered secondarily by traumatic factors. In the case of Kreuz and in my case 2 the process of reorganization followed the first modus. The focus of subchondral necrosis became resorbed and slowly replaced without leading to much deformity. Up to this point it had behaved in exactly the same way as does pseudoosteochondritis dissecans. The only difference was in the zone of demarcation; in pseudo-osteochondritis dissecans the zone of demarcation is osteoporotic; in Kreuz's case and in my case it was osteosclerotic. I have explained the osteoporotic zone, considering it as pseudoarthrosis. The explanation of the sclerotic zone of demarcation is as follows: The necrotic subchondral area undergoes revitalization in a centrifugal direction; the bony tissues close to the joint cartilage are the last rests to be resorbed and replaced. The zone of sclerosis is, as I shall show by the histologic picture in the following case, primarily a zone of reaction. This reaction is probably due to stimulation of the living bone marrow to osteogenesis by toxic products from the decomposition of the necrotic marrow. Primarily it is of no static importance. Later, however, if necrotic spongy bone is resorbed and the mechanical firmness of the epiphysis is weakened, the central portion of the epiphysis will be exposed to further mechanical irritation, which will result in bone apposition and sclerosis. This is essentially the mechanism observed in cases of hypertrophic arthritis, in which the

superficial spongy bone close to the joint surface is fortified by apposition of new bone as an expression of the increased mechanicostatic demands of this denuded articular area.

The following case has not been studied carefully from a clinical standpoint. The bilateral lesion of the hip was unrecognized during life, and no roentgenogram was taken. The patient died in a charitable institution in Vienna, and it was the postmortem examination which disclosed the peculiar lesion of both hip joints.

Case 3.—A 77 year old woman was observed at autopsy.[10] The clinical history was poor. The patient was supposed to have fallen two years before death. She had been unable to get up because of sudden severe pains in both hip joints. The pain was associated with frequent muscle spasms in the lower extremities. There was some gradual improvement, but she had remained bedridden since the day of the fall. Both knee and hip joints were restricted in motion, and there was spastic flexion contraction of the knees and hips. (Encephalomalacic areas were observed in the basal ganglions and the inner capsule. The autopsy did not reveal a fracture of the neck of the femur, which had been suspected clinically; however, there were interesting findings in both hip joints, which I consider it worth while to discuss in more detail.

The head of the right femur looked as though it had been flattened, impressed and made smaller by pressure from above. The joint cartilage was preserved; it was even smooth and free from arthritic changes except where the joint surface was flattened; there it showed three folds, as though by resorption of the underlying bone the cartilaginous cover had become too large and for this reason had become folded. Over the posterior aspect of the head the joint cartilage was eroded and even absent over a larger area, as a sign that a large area of the joint surface was out of contact with the acetabulum, owing to the ankylosis. There were also a few fibrous adhesions.

A surprising picture was presented by the cut surface. The femoral neck was normal, but the head had disappeared to a great extent; it showed, nevertheless, a fairly well preserved cartilaginous cover. The diminution in size of the head was caused by necrosis of a large subchondral portion of the epiphysis, which had already undergone extensive resorption. The rest of the necrotic area was still present below the cartilage, yellow and dense like caries necrotica. A wide zone of hyperemic fibrous tissue was present between the necrotic and the normal spongy bone. Included in the fibrous tissue was bluish transparent cartilage which differed considerably from the old yellow, opaque joint cartilage. The spongy bone of the femoral neck showed some signs of sclerosis just under the fibrous zone of demarcation.

To explain the disappearance of the head of the femur and the pleat formation of the joint cartilage, it should be mentioned that a fracture line was running through the necrotic spongy bone immediately below the joint cartilage. Thus, two factors were responsible for the loss of spongiosa: (*a*) absorption by fibrous tissue along the zone of demarcation, and (*b*) friction of the osseous surfaces along the fracture space. The spongy bone was ground to detritus. The fracture space, however, because of the intra-articular pressure, remained capillary, and all the detritus was pressed into the narrow spaces.

10. Freund, E.: Virchows Arch. f. path. Anat. **261**:287, 1926.

The head of the left femur was not as much deformed and not quite as small as that of the right. The deformation was not on the upper but more on the medial surface, at the site of the fovea capitis. The joint cartilage as a whole was well preserved, but in this also folds were present, which, if the joint was observed from the surface, remained almost unnoticed because fibrous tissue had filled the valley between the cartilaginous folds. The posterior surface revealed an extensive area of cartilage absorption exactly like that in the right hip joint.

The cut surface resembled that of the right femoral head. Only the localization of the area of necrosis was different. The yellow color and the density of the necrotic spongiosa were suggestive of tuberculous caries, but the absence of erosion of the cartilage easily ruled out tuberculosis. The cut surface also revealed

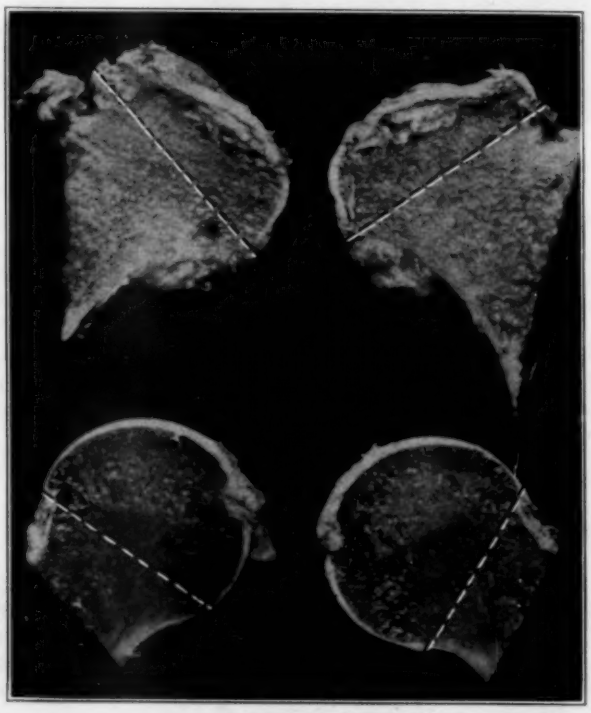

Fig. 3 (case 3).—Frontal sections through the right femoral head compared with sections of a normal joint, to illustrate the loss of osseous substance from the epiphysis through subchondral aseptic necrosis. The dotted line indicates the borderline between the head and the neck of the femur. The joint cartilage is fairly well preserved but is very irregular over the depressed area.

that the head was considerably smaller than normal. Tracing a circle with the radius of the normal joint margin, one realized that the necrotic area was decidedly displaced inward and that the gradual resorption of necrotic spongiosa had led to the fold formations of the joint cartilage.

Both femoral heads were cut in slices, and numerous sections were studied histologically. I refrain from giving a detailed histologic report, which has been published elsewhere,[10] and offer here a brief summary which will help in the understanding of this peculiar disease.

A subchondral portion of the epiphysis had undergone aseptic necrosis of the spongiosa and bone marrow. The necrotic focus of the left femoral head was considerably larger than that of the right. A fracture line of intravital origin passed through the necrotic bone close to the joint cartilage. There was no sign of callous formation, because the fracture ran through necrotic bone entirely, far away from living bone marrow. Constant friction of the fracture surfaces ground up the necrotic bony trabeculae near the fracture space to a fine powder which filled the fracture space as well as marrow spaces. On the other hand, the loss of subchondral bone deprived the joint cartilage of its solid support, and it showed some deep implications, leading in some places to complete and multiple fractures.

The spongiosa of the head of the femur at the border between the necrotic and the living bone marrow still showed continuity in some places, and in others there was complete separation by a zone of fibrous tissue. There were no stages of dissection between these extremes. The separation occurred within the area of necrotic osseous tissue which in part remained included within the fibrous zone of dissection.

Where the bony trabeculae passed without interruption from the focus of subchondral necrosis into the living central portion of the epiphysis, a gradual replacement of the necrotic bone marrow by fibrous marrow took place, and soon afterward an apposition of primitive dark blue fibrous bone occurred along the surfaces of the necrotic trabeculae. The necrotic spongiosa extended quite far into the living fatty marrow below the fibrous marrow spaces. The trabeculae within the necrotic area, deprived of all immediate possibilities of resorption, had preserved the same thickness as they had the day they were effected by aseptic necrosis, while the spongiosa in living fat marrow showed considerable signs of atrophy from inactivity. The subchondral necrotic bone, dense and free from all resorption, gave a dark shadow in the roentgenogram, thus contrasting sequestrum-like with the porotic surroundings. Contributory to this relative density was the accumulation of calcified detritic material of ground-up bony trabeculae and calcified joint cartilage in the necrotic narrow spaces.

Where sequestration of the necrotic bone has occurred, the picture was different. A wide zone of dense hyperemic fibrous tissue interrupted the continuity of the necrotic spongiosa. Necrotic trabeculae were found above and below the fibrous zone of demarcation, but not within it. The trabeculae below the fibrous tissue again showed the dark blue endosteal layers of primitive fibrous bone, which even extended over living trabeculae. Thus resulted a zone of osteosclerosis immediately below the dissecting fibrous tissue. The osteosclerosis could be considered in part as due to toxic irritation of bone marrow (through the resorption of toxic products from the decomposition of necrotic bone marrow); in part, however, it was the expression of increased mechanical irritation, the subchondral necrotic area with every movement of the joint being pressed against living spongiosa. The dissection through the necrotic bone took place typically by lacunar resorption along the fibrous zone of demarcation.

This revealed clearly that the process of reorganization may be different in different areas. The necrotic bone marrow may become replaced by fibrous tissue, and new bone may be laid down on the surfaces of old osseous trabeculae. The other form also leads to substitution of necrotic bone marrow by fibrous tissue, but at the same time resorption of the necrotic trabeculae takes place, with sequestration of the necrotic bone. The first form may be called organization; the

second sequestration of the area of aseptic necrosis. The reason for this difference in the process of reorganization is not always clear; mechanical factors, shearing stresses or ultraphysiologic pressure may be of importance. A better understanding of these factors would be of great help in prognosticating whether in a certain case of aseptic necrosis osteochondritis dissecans will occur. It seems that the size of the focus of necrosis is of greatest importance. A large focus which includes most of the epiphysis will hardly ever become sequestrated. Dissection may take place at a later stage of reorganization, when the necrotic bone is reduced to a relatively small subchondral portion. The mechanical irritation of this region apparently has a decisive influence on the process of reorganization. Therefore it is more likely that a dissecting process will be an early response to aseptic necrosis if the latter involves only a smaller subchondral portion of the epiphysis. It will not be observed at an early stage of reorganization if the necrosis is extensive and involves the greater part of the epiphysis. In such cases, dissection or sequestration will be a late complication, caused by mechanical irritation of the zone of organization as soon as the latter reaches the subchondral area and the danger zones there.

The anatomic study of this case furnishes the key to the full understanding of aseptic necrosis of bone and the different forms of reorganization. Although not an outstanding instance of osteochondritis dissecans, it shows better than a true case could that osteochondritis dissecans is only a form of reorganization which may but does not necessarily follow the occurrence of bone necrosis.

Certainly the age is most unusual in this case. Physicians are accustomed to finding aseptic necrosis in childhood or adolescence. In old persons it may occur as a result of severe trauma; for instance, following fracture of the neck of the femur, partial or complete necrosis of the proximal fragment may occur; in its idiopathic form, however, which may lead to osteochondritis dissecans, it has never to my knowledge been observed in a person of such old age as the patient in case 3. One might think, in view of the poor clinical history in this case, that the aseptic necrosis of both femoral heads had been of many years' duration. One cannot rule out the possibility that it started in the prime of life and lasted several decades without coming to full organization. The fall two years before death, mentioned in the history, certainly could not be responsible for the lesions in both femoral heads, which from a pathologic standpoint suggested a difference in duration. (This seems to be the rule in cases of bilateral osteochondritis dissecans; roentgenologically the condition is almost always more advanced on one side than on the other. One side may present clinical symptoms while the other is clinically normal despite considerable roentgenologic changes.) There is as yet no way to determine the duration of a focus

of aseptic necrosis, but it usually is much older than the clinical history would lead one to believe. If idiopathic aseptic necrosis should really be a disease of young persons exclusively, case 3 would show that the condition may be present for decades, with disablement delayed until the last two years of life. However, one cannot rely too much on this argument. It is altogether hypothetic, so little being known of the case history. I can say only that the definite trauma two years before death must have acted on bone tissue already pathologic; it could have been responsible for the subchondral fracture through the necrotic bone and for a sudden arthritic reaction.

Case 3 has a great resemblance to cases 4 and 6, in which the patients were robust males who showed essentially the same clinical and roentgenologic symptoms and the same underlying pathologic condition.

CASE 4.—This case was observed[11] in the orthopedic department of the University of Iowa. A 45 year old man complained of pain and stiffness of the right hip. Two years before admission, while he was carrying one end of a long plank, he slipped on wet ground and was knocked down backward. The plank struck him over the right hip anteriorly. There was immediate pain around the right hip. He walked with difficulty, and his superintendent assigned him a lighter job for the remainder of the day. Roentgenograms were not taken, but heat therapy was advised. There was great improvement, but the pain did not disappear completely. He returned to work in two weeks. After four or five weeks he had to stop working again because of pain in the hip and a limp. He was then in bed four or five months. During the winter months, especially, pain and stiffness in the hip joint were severe. About six months before admission the hip became almost completely rigid, and since that time he had been unable to put on his right shoe. At the time of his admission to the clinic, pain was less marked, and for the last year changes in the weather had had little effect. The patient had lost 20 pounds (90.1 Kg.) since the accident.

On physical examination he was seen to be a well developed, powerfully built man who walked with a marked limp on the right side. The right lower extremity was held in about 25 degrees external rotation, 15 degrees abduction and 10 degrees flexion; only 10 degrees of flexion was possible. There was slight tenderness over the anterior aspect of the hip. There was no atrophy of the thigh.

The patient was admitted for physical therapy elsewhere, under which he improved considerably. The pain disappeared almost completely, and there was increase of motion (flexion from 165 to 120 degrees). He was then discharged to continue with heat treatment at home. He returned again after one year. There was no improvement; the hip was practically rigid, showing marked flexion-abduction and external rotation contracture.

Roentgenograms were taken at different intervals (the earliest six months after the accident). They always showed more or less the same rather unusual picture. The head of each femur contained a dark shadow. In the left femur the shadow was wedged shaped. The base of the wedge comprised almost the entire joint surface; the point was in the center of the neck. In the right femur the sclerotic area involved the subchondral region, but the other part of the head showed irregular bony trabeculation. Through the upper part of the head

11. Freund, E.: Ann. Surg. **104**:100, 1936.

of the femur, opposite the roof of the acetabulum, extended an irregular fracture line, more or less parallel to the joint surface, separating a slightly flattened lentil-shaped fragment from the other portion of the femoral head. Where the fracture line ended at the joint surface, a small spicule of bone protruded into the joint cavity. The joint cavity was of normal width and the joint surfaces were smooth, except that beginning formation of marginal exostoses could be seen on the inferior part of the ilium, on the right side.

From the clinical and roentgenologic findings, the diagnosis of degenerative (hypertrophic) arthritis of the hip joint was made. It was thought that the condition probably had developed on the basis of an intra-articular fracture of the head of the femur. The dark shadow of the femoral epiphysis was unusual for hypertrophic arthritis but was considered as representing a pronounced degree of reactive osteosclerosis in the subchondral zone.

Because there was practically no improvement despite protracted physical therapy, an exploratory operation, followed possibly by an arthroplasty, seemed indicated.

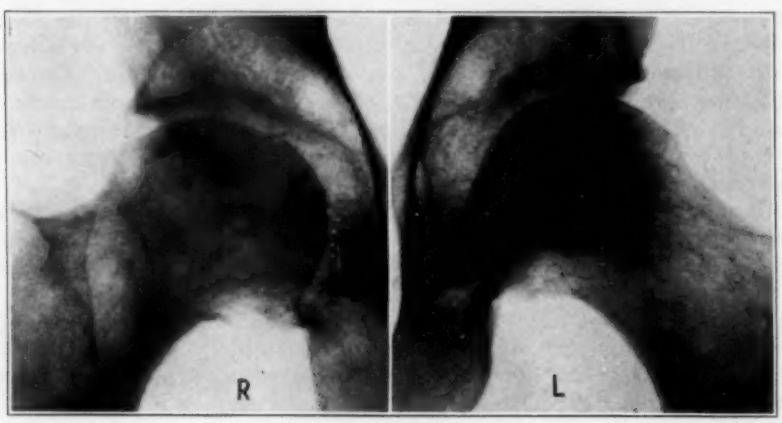

Fig. 4 (case 4).—Anteroposterior view of both hip joints. The dark shadow in the epiphysis represents an area of aseptic necrosis, wedge-shaped in the left femur without deformity of the head. There is a subchondral irregular fracture line through the subchondral zone of the weight-bearing portion of the right femur, with a small spicule of bone, deriving from the subchondral bony lamina and pointing into the joint cavity. The resorptive changes of the necrotic bone are more advanced in the right femur. There is deformity of the femoral head, consisting of a depression of the upper pole and beginning hypertrophic arthritic changes at the joint margins.

Operation was performed, the right hip joint being exposed between the tensor fasciae latae and the gluteus medius muscles. The joint capsule was considerably thickened. It was incised, and the head of the femur was dislocated into the wound. It was markedly deformed; it was enlarged and showed a cartilaginous cover with pronounced degenerative changes and unevenness. The ligamentum teres was still present, and there were marginal exostoses around the entire joint surface. Eroded areas of the joint cartilage were relatively scarce. The head of the femur was trimmed to reduce its size, and a very unusual picture was encountered. For the greater part the head of the femur was necrotic. The

spongy bone was dense, yellow and not bleeding. The yellow necrotic areas were surrounded by hyperemic, more porotic portions which were separated from the necrotic bone by a sharp line of demarcation. Almost all of the necrotic bone was removed, together with the joint cartilage. The divided head was covered with a flap of fascia lata, which was also sutured to the joint capsule. The head was reduced and the capsule closed.

The findings at operation clearly explained the roentgenologic picture. The dark shadow represented an area of aseptic necrosis of the epiphysis. Histologically the involved area presented essentially the same pictures as the areas of necrosis in case 3 except that in the latter instance the lesion was more advanced. Dissection of the necrotic tissue had started but had not yet reached such a degree as to become manifest in the roentgenogram. Therefore, one cannot call the condition osteochondritis dissecans, although it would have slowly developed into this. The condition was bilateral idiopathic aseptic necrosis of the femoral head, complicated by a subchondral fracture and articular symptoms before the process of substitution was fully changed to a process of sequestration.

The patient was followed up for two years after the operation. For more than one year he complained very much of pain and stiffness in the hip, although the objective examination showed a satisfactory result. (The lawsuit for workingmen's compensation was still pending.) About eighteen months after the operation the patient himself noticed much improvement. He discarded his crutch and walked well with a cane. The muscles around the hip became stronger, and active motion was rapidly increasing. The passive range of motion was: for flexion, 75 to 80 degrees; for abduction, 25 degrees; for adduction, 0; for internal rotation, 5 to 10 degrees, and for external rotation, 40 degrees. There was about 1 inch (2.5 cm.) of shortening, and atrophy of the right thigh was still marked.

Apart from the interest this case arouses from the roentgenologic and pathologic standpoints, it presents an important medicolegal aspect which frequently has to be considered in cases of this type when the patients are otherwise normal workingmen in the prime of life. This case was a "compensation case." The patient claimed that his disability started with an industrial accident. A direct trauma to the hip was followed by pain and stiffness. The earliest roentgenogram was not taken until six months after the accident. Roentgenograms taken then, on several occasions, showed the conditions mentioned. It is hard to make a definite statement as to how long the aseptic necrosis was in existence, that is, whether it was half a year old or older. It probably was older, but there is no proof for this assumption; only a roentgenogram taken the day of the accident or shortly after would settle this question. Unfortunately for the patient (also from a practical standpoint) no roentgenogram had been taken immediately. However, regardless of whether the aseptic necrosis of the head of the right femur was six months old or older, it is certain that the trauma which the patient sustained could not have been responsible for the aseptic necrosis of both femoral heads. The patient never complained of the left hip, which showed essentially the same picture as the right. There was only

one difference—in none of the numerous roentgenograms was there a subchondral fracture line in the left hip joint. It was present in the earliest picture in the right femoral head. It is possible—and this is the only thing which speaks in favor of the patient—that the subchondral fracture of the right femur was due to the industrial accident. The aseptic necrosis, evidently in this case "idiopathic" and without a traumatic cause, must have preceded clinical symptoms for a long time, possibly for years. The secondary subchondral fracture (a pathologic fracture because it occurred in necrotic bony tissue) was intra-articular and had certainly led to augmentation of arthritic symptoms; it may even have been responsible for the very beginning of clinical symptoms. On the other hand, it is true that epiphysial aseptic necrosis per se may be followed by degenerative and hypertrophic arthritic changes without the occurrence of a definite secondary complicating trauma. Therefore, from a medicolegal point of view the patient has to be considered in the same light as a patient with metastatic malignant tumor or with Paget's disease who sustains a "spontaneous" fracture of the affected bone. His claim for compensation had to be rejected, on the basis that his primary osseous disease, i. e., aseptic necrosis, was certainly not caused by the industrial accident. The subchondral fracture may have been the result of the injury, but since such a fracture develops so frequently without injury, the fracture in this case should not be attributed necessarily to the trauma. It is to be expected that symptoms similar to those present on the right side will also develop sooner or later on the left side. This will prove that the entire pathologic process in this case was essentially independent of the industrial accident. A somewhat similar problem was presented in the following case.

Case 5.—A 31 year old Negro, a butcher, complained of pain in the left hip, which came on gradually.[11] The only fact the patient could offer in explanation was that during his work he had to assume a certain position in which his hip tired easily. The hip became stiff but limbered up spontaneously. On physical examination, mild flexion contracture of the left hip joint with some limitation of motion was found. The results of laboratory tests were essentially negative, but roentgenograms showed an unusual picture of irregular osteoporosis in the femoral head and slight narrowing of the joint space. Physical therapy followed by immobilization in a plaster of paris cast did not afford any relief of symptoms. Biopsy of material from the head of the femur and the joint capsule was performed. A typical picture was encountered of subchondral aseptic necrosis undergoing reorganization by fibrous bone marrow. There were nonspecific chronic inflammatory changes in the joint capsule, but not to a greater extent than is expected in a case of aseptic necrosis of bone.

The follow-up disclosed increasing stiffness of the hip joint, with pain on weight bearing. A roentgenogram taken more than one year after the first showed an increase in the irregularity of the osseous structure without leading to the picture of osteochondritis dissecans. This case did not permit a definite diagnosis. It was not studied long enough. In several ways it differed from a

case of aseptic necrosis. The narrowing of the joint space with marked restriction of motion suggests more a destructive articular process. A complement fixation test for gonorrhea gave a 4 plus reaction.

Mouchet [6] stated that gonorrhea is of possible etiologic importance in cases of osteochondritis dissecans of the hip joint, but I am skeptical concerning such a connection. I reported case 5 because it has several features in common with cases of osteochondritis dissecans, but it is not sufficiently clear from a diagnostic standpoint to warrant further conclusions.

CASE 6.—A 34 year old man, a painter, complained of pain in the hip and knee joints, especially of the left side. The trouble had started rather acutely with pain in the left leg one morning when he awoke, about two years previously. The pain at first was in the region of the knee but later settled in the left hip. There was no direct relation to a trauma, although a short time previous to the onset

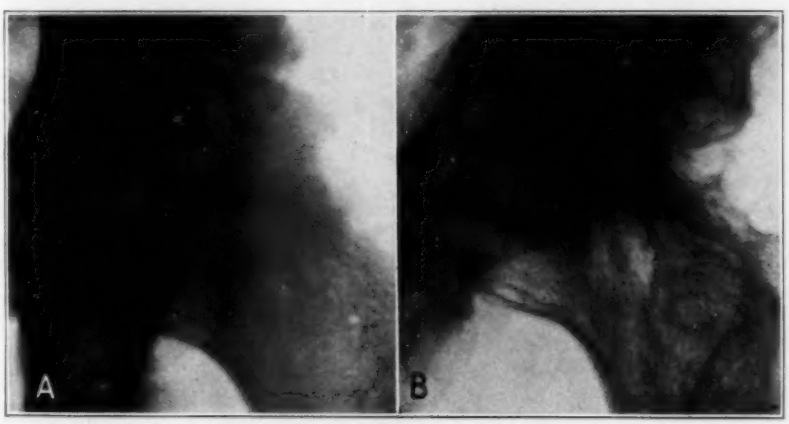

Fig. 5 (case 5).—Aseptic necrosis of the head of the left femur in two different stages of reorganization. *A,* irregular osteoporosis in the epiphysis, due to reorganization of aseptic necrosis. The subchondral area is still dark. There is slight narrowing of the joint space (August 1935). *B,* reorganization of most of the head, with the bony structure still irregular. The small subchondral dark area represents the rest of the necrotic epiphysis. There are arthritic changes at the joint margins (November 1936).

of subjective symptoms the patient had had a fall from a ladder, landing flat on his back. He had had to stay in bed for two days and had been unable to work for about a week. The left leg gradually became weaker, and the motion in the left hip joint was much impaired. He tired very easily.

On physical examination he was found in good general condition. His arms and trunk were powerfully built and contrasted considerably with the lower extremities, which appeared atrophic. He walked with the use of a cane and with a decided limp to the left. There was a slight adduction contracture of the hip joint and atrophy of the left lower extremity. There was no shortening. The left hip joint showed limitation of motion, flexion from 180 to 90 degrees, external rotation of 5 degrees and all other motions absent. The right hip joint, which

did not give much subjective trouble, also showed considerable restriction of motion (flexion from 180 to 75 degrees, adduction 20 degrees, abduction 25 degrees, internal rotation 0, external rotation 5 degrees). There was some tenderness over the anterior aspect of the left hip joint. The Trendelenburg test was negative on the right and questionable on the left. Clinical examination of the knee joints showed them to be normal.

The clinical symptoms suggested a lesion affecting both hip joints, the left more than the right. The subjective symptoms of pain in the knee joints could be explained as pain referred from the hips. The limitation of motion in the left hip joint, with the adduction contracture and absence of more general symptoms, suggested the diagnosis of simple hypertrophic arthritis, and the restriction of motion of the right hip joint well agreed with such a diagnosis. However, the age of the patient, without a history of disease of the hip joint in early childhood or in adolescence, made the clinical diagnosis of hypertrophic arthritis doubtful. A direct traumatic lesion could safely be ruled out because both hip joints seemed to be affected, the left more than the right, and the one trauma mentioned in the history could not be made responsible for symptoms in both hip joints. From a clinical point of view, therefore diagnosis had to be deferred.

Roentgenograms were taken and revealed an unusual but characteristic picture. There was considerable deformity of both femoral heads, more pronounced in the left than in the right. The deformity involved mainly the weight-bearing portion, especially the upper outer pole. The joint surface of the left femoral head was irregular, flattened over the lateral portion and impressed. The upper part of the epiphysis appeared sequestrum-like in a very dark shadow, which toward the periphery became cloudy and seemed almost completely separated by a denser zone of osteoporosis from the rest of the epiphysis. Beyond this almost bone-free zone a distinct but irregular band of sclerosis was found, which thus demarcated definitely the entire diseased area from the femoral neck. Several well circumscribed, cystlike areas of osteoporosis were found in the neck, close to the zone of demarcation. At the joint borders, especially opposite the outer edge of the roof of the acetabulum, hypertrophic arthritic changes were noticed in the form of marginal exostoses. There was slight lateral subluxation of the head of the femur.

The changes in the right hip joint were essentially the same, but they were less advanced and less extensive. Here, too, the upper outer portion of the femoral epiphysis appeared in a dense shadow which became loosened from the lateral surface of the neck. At this area the shadow was more cloudy, with irregular osseous structure. No definite zone of demarcation was visible, although it seemed that some osteosclerotic changes had taken place at the lower surface of the dark area. The joint surface over the diseased weight-bearing portion was irregular; it was broken into several pieces and was flattened and depressed. The joint space of each hip joint was of normal width or or even wider than normal, corresponding to the flattening deformity of the femoral head.

From this characteristic picture the diagnosis of bilateral aseptic necrosis of the femoral head was made. There was definite sequestration (osteochondritis dissecans) in the left femoral head, while the process of reorganization in the right hip was still aiming at gradual substitution of the necrotic area. From a roentgenologic point of view the case was similar to, indeed almost identical with, cases 3 and 4. Once one has become acquainted with the roentgenologic appearance in such cases, the diagnosis can be made easily. (It seems that in a number

of such cases the condition is considered chronic arthritis, usually hypertrophic arthritis, as long as the existence of a zone of demarcation does not suggest the diagnosis of osteochondritis dissecans. The underlying pathologic process, the idiopathic aseptic necrosis, is apparently not taken into diagnostic consideration frequently enough. I do not doubt that with more attention and better knowledge the recognition of this peculiar condition will become easier and the number of clinical observations will grow.)

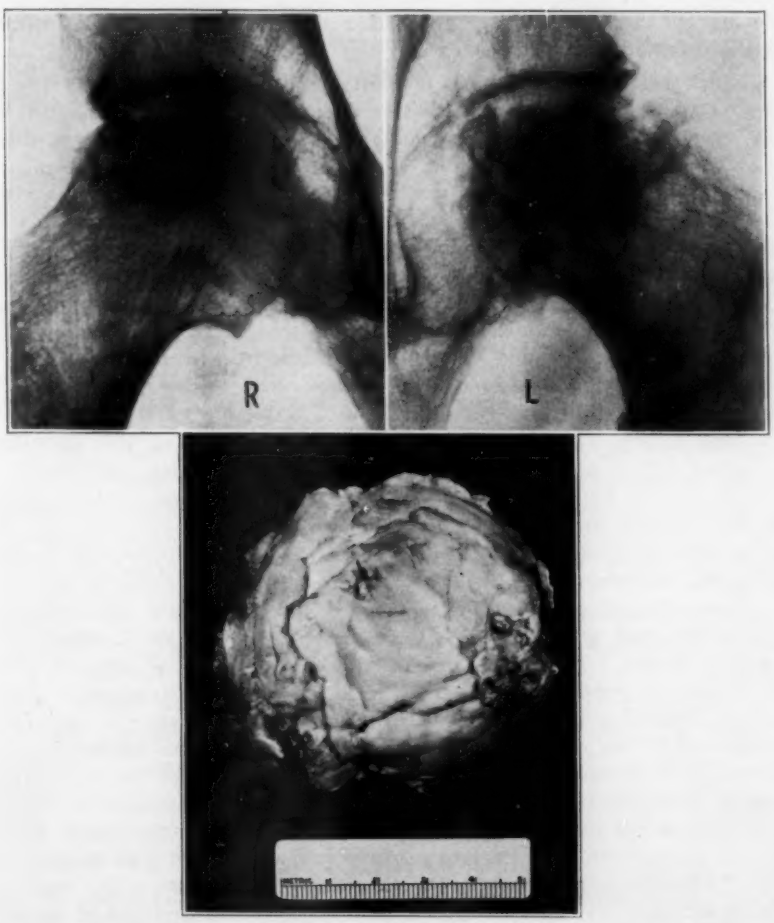

Fig. 6 (case 6).—Anteroposterior view of both hip joints and photograph of the left femoral head seen from above. Note the dark shadow of aseptic necrosis in the upper outer pole of the right femur, with depression and corresponding widening of the joint space. There is beginning absorption of the necrotic area from below. More marked changes are discernible in the left femur, with the pathologic picture of osteochondritis dissecans. Note the separation of the dark, necrotic epiphysis by zones of increased and decreased density. There is pronounced deformity, with depression of the necrotic area and lateral subluxation. Cystlike areas of osteoporosis are present in the neck of the femur. The photograph reveals the unevenness of the joint cartilage, with its folding and perforation, its erosion around the fovea capitis and its wreathlike marginal exostoses.

The disability with pain and restriction of motion, and the character of the pathologic process, made all conservative means of treatment appear hopeless. The only treatment of promise seemed to be surgical. Simple removal of the joint body, such as is so frequently carried out with best results in cases of osteochondritis dissecans of the knee joint, was out of the question in a case in which the necrotic body involved practically the entire weight-bearing portion of the joint surface. Simple removal of the sequestrum would lead to such a deformity of the head of the femur that the patient certainly would not be benefited by the intervention. For this reason a more radical reconstructive operation was performed in this case.

The left hip joint was exposed through a Smith-Petersen incision. The joint capsule was incised in the form of a T, and the head of the femur was dislocated with some difficulty. It was considerably enlarged, misshapen and mushroom-like. By removal of the entire joint cartilage with the underlying necrotic bone, the upper end of the femur was remodeled so as to form more or less a cone-like stump of rather dense spongy bone. It was smoothed and covered with a flap of fascia lata. The hip was reduced and the capsule closed tight. To lengthen the neck of the femur and to improve the action of the abductor muscles by establishing a better lever at the upper end of the femur, the greater trochanter with the insertion of the abductor muscles was wedged out according to Albee's reconstruction procedure, and the gap between the trochanter and the neck was filled with wedge-shaped pieces of bone removed from the crest and wing of the ilium. The wound was closed in layers, and a double hip spica cast was applied.

A little hole in the cartilaginous cover in the center of the joint surface was of interest. This hole established a communication between the subchondral marrow spaces and the joint cavity. The slightest pressure on the joint cartilage over this area squeezed some bloody fluid out from the head. There was no doubt that by this valvelike opening powdered material could be drained out from the subchondral marrow spaces, especially on pressure, thus causing a decrease in the amount of substance composing the bony epiphysis. (This is therefore a third factor which leads to decrease in size of the subchondral necrotic area. In the discussion of case 3 I mentioned the resorption of necrotic bone by fibrous bone marrow and the grinding up of necrotic trabeculae along the subchondral fracture line, with massaging of the osseous detritus into the marrow spaces. Both factors were present in this case besides the loss of powdered osseous substance through the hole in the joint cartilage.) Sections through the area of the hole revealed, again, a subchondral fracture space running more or less parallel to the joint surface and ending just at the point of perforation of the joint cartilage. Detritic material, accumulated in the fracture space, gradually seeped into the free joint cavity. There it became resorbed by the synovial membrane, which under this constant irritation by foreign material in the joint fluid proliferated markedly. Hyperplastic synovitis resulted, with thickened tags and villi at the joint margins.

The condition described, which from a roentgenologic standpoint was certainly osteochondritis dissecans, at least of the left hip, formed with the conditions in cases 3 and 4 a group of identical conditions of the hip joint in slightly different stages of reorganization. Primarily all 3 were bilateral aseptic necrosis. They presented the picture of osteochondritis dissecans late in their course, apparently only as a secondary complication of the process of reorganization.

From a review of the reports in the literature and from my own observations [12] a number of definite conclusions can be drawn. Osteochondritis dissecans of the head of the femur is certainly rare. However, it may be that with more interest in this peculiar lesion the diagnosis will be made more often. Especially in young adults, hip trouble diagnosed roentgenologically as chronic arthritis may be partial aseptic necrosis becoming osteochondritis dissecans. One does not need the presence of a zone of demarcation to consider aseptic necrosis. The dissection is a rather late occurrence, and the roentgenologic appearance of osteochondritis dissecans is relatively insignificant from a pathologic standpoint, that is, the separation of a subchondral portion from the rest of the epiphysis is by no means pathognomonic of epiphysionecrosis. The line of dissection, if it appears at all, always appears late and may have two different meanings. It may be the expression of a zone of pseudoarthrosis complicating the end of a process of reorganization. A relatively small subchondral focus of aseptic necrosis may have become fully revitalized and reconstructed but, probably because of mechanical irritation during the active phase of reconstruction, the reorganized area may not have found firm osseous union with the rest of the epiphysis. Such a lesion shows a characteristic lentil-shaped, usually slightly osteoporotic body separated from the neighboring bone by a sharp bone-free zone. I have designated such a condition as pseudo–osteochondritis dissecans. It has the characteristic roentgen picture without being true osteochondritis dissecans. In other words, the roentgenogram is misleading. The pathologic process always precedes clinical symptoms and the indications for taking a roentgenogram, usually by several years. It seems that the active pathologic changes in such femoral heads occur in childhood at the usual time of Perthes' disease or a little later. Just as in many cases of Perthes' disease fine osteoporotic lines may persist for a long time after the characteristic stage of fragmentation, so also in cases of partial aseptic necrosis the reorganized focus may remain divided from the rest of the epiphysis by a fibrous zone. It may again become incorporated, with complete restitution of a normal epiphysis (Gold,[3] second case). I feel that in every case of this type the epiphysial lesion is a relatively benign lesion. In every case it probably would heal perfectly if the leg were immobilized during the active stage of the disease. Unfortunately, the active stage, as a rule, remains clinically and subjectively unnoticed. Subjective symptoms arise when the actual pathologic process is over and articular complication sets in, probably due to unevenness of the cartilaginous cover, with synovial reaction. At this clinically early

12. Freund, E.: Active and Passive Pleat Formation of Joint Cartilage, Arch. Path. **18**:186 (Aug.) 1934.

and painful period consideration should be given to immobilization in a hip spica cast to give the zone of pseudoarthrosis a chance to fill in so that firm consolidation with the epiphysis may be reestablished. I do not think that such a reorganized area will ever come to complete separation, with appearance of a free joint body. It is usually situated at the upper pole of the femoral head and is well protected by sound and thick joint cartilage.

Inasmuch as the process of reorganization does not tend to sequestration, the only mode of separation is on a traumatic basis. It is difficult, however, to conceive how trauma could lead to dehiscence of the joint cartilage around the margins of the subchondral body. The similarity of the roentgen appearance in such cases with that in cases of osteochondritis dissecans of the knee joint suggests surgical treatment. I doubt, however, that operation would be of great benefit, considering that clinical discomfort is not caused by "internal derangement" of the hip joint or by a free joint body. Surgical removal of the subchondral body with its cartilage cover would aggravate the symptoms by creating a deformity at the most important part of the joint, that is, at its weight-bearing portion.

Still the aforementioned observation of Bergmann [2] suggests that osteochondritis dissecans of the hip joint may lead to the formation of a free joint mouse with locking of the joint. However, Bergmann's case is different from the other cases described. The body derived from the region of the fovea capitis where, because of the thinness or lack of joint cartilage, a separation can take place much more easily than at the free weight-bearing joint surface. Although there is no doubt as to the correctness of Bergmann's diagnosis of osteochondritis dissecans, one cannot help but feel that his case is rather unusual as far as the clinical symptoms and the localization of the body are concerned. As far as I could find out, in no other case has osteochondritis dissecans of the hip joint led to a free joint mouse.

There is another form of pseudo-osteochondritis in which the line of demarcation between the subchondral area in reorganization and the rest of the epiphysis is represented by a sclerotic zone. This is shown by the experience of Kreuz [9] and by my own experience in case 2. Here, too, mechanical factors besides a toxic stimulus to osteogenesis are probably responsible for the development of the sclerotic zone. In either form, whether it leads to a zone of pseudoarthrosis or one of osteosclerosis, the reorganization of the subchondral area takes place in centripetal direction.

The patients in this group were young. With the exception of the patient in case 1, who was still in the first decade of life, they were in the second and third decades. The osseous focus in separation was relatively small, and the prognosis seemed to be quite good. But there

is another group of cases in which the patients are adults in the fourth and fifth decades of life. Males, as those in the first group, seem to be by far more affected than females, and the patient usually is a robust type of man doing hard physical work. Very commonly, but not always, both hip joints are involved; as in Mouchet's [6] case and in case 5, the condition being usually a little more advanced in one than in the other. A large portion of the epiphysis, for reasons which are entirely unknown, undergoes aseptic necrosis. The area of necrosis always is much more extensive than in the first group of cases; the greater part of the epiphysis and even portions of the femoral neck may be involved. Roentgenograms taken in the early stages show characteristically a wedge-shaped dark shadow, the point of the wedge being in the center of the head or neck and the base comprising the entire joint surface. The joint surface in such cases is fairly even, and motion may be almost normal. Nevertheless, even in such early roentgenologic stages the condition is considerably advanced from a pathologic point of view. When the shadow of the necrotic epiphysis appears darker than normal there must be a fracture in the subchondral area, with grinding up of necrotic bony trabeculae. The aseptic necrosis will lead to reactive changes from the side of the living bone marrow, aiming at reorganization of the necrotic head in the centrifugal direction. As long as this process of reorganization is not interfered with by mechanical factors, it will follow the way of gradual resorption of the old necrosis and substitution by new bone. This slow process is the same as that observed when large bone grafts are "taking." A great many of the necrotic trabeculae remain; they receive only sheaths of new bone. The further the process of reorganization advances toward the joint surface, the more it will become complicated by mechanical irritation. The gradual loss of bone by osteoclastic bone absorption at the lower periphery of the area of necrosis will weaken the mechanical support of the joint cartilage, which will break in or become folded to adapt itself to the decreasing osseous epiphysial substance. If joint motion and weight bearing are continued, the constant mechanical irritation will change the process of gradual substitution to a process of dissection, which will separate the remaining subchondral area of necrosis from the reorganized portion of the epiphysis by a zone of firm fibrous tissue, producing osteochondritis dissecans.

It is of greatest interest and must be emphasized that the zone of dissection in true osteochondritis dissecans is a late occurrence just as it is in pseudo-osteochondritis dissecans. Dissection does not seem to be a primary response to aseptic necrosis of the epiphysis. It takes place only when the primary process of creeping replacement is interfered with by mechanical irritation and more marked trauma. The zone of dissection, therefore, never separates the entire focus of necrosis; it runs through

the necrotic area, a part of which has already undergone revitalization. On histologic examination one finds necrotic bony trabeculae above and below the dissecting fibrous tissue. Below, they are included in revitalized bone marrow, which lays down on their endosteal surfaces new bone; above they are still untouched by the process of organization and lie in necrotic bone marrow. This clearly shows that there was first the attempt at substitution of necrotic tissue by living tissue, which attempt was annihilated before it could fully reach its purpose.

Therefore, osteochondritis dissecans, as well as pseudo–osteochondritis dissecans, is not a clinical or pathologic entity. Both conditions are merely the morphologic manifestation of a secondary complication during the process of reorganization which primarily aims at complete substitution of a more or less extensive area of epiphysionecrosis. In one form of pseudo–osteochondritis dissecans it is the already reorganized and relatively small subchondral focus of necrosis which does not find osseous consolidation with the rest of the epiphysis; it remains separated by pseudoarthrotic fibrous tissue. In true osteochondritis dissecans a relatively much larger portion of the subchondral necrosis, not yet invaded by living fibrous tissue, is cut loose from the reorganized epiphysis by a more or less continuous zone of fibrous tissue. In both instances it is, without doubt, the use of the joint which interferes with the restitutio ad integrum of the epiphysis. Primarily, complete restitution can be expected in every case of reorganization of aseptic necrosis of bone. If adequate immobilization could be carried out at the critical period of the process, secondary trauma would not interfere with reorganization, and dissection would never occur.

Thus, trauma is certainly of great influence on the final outcome. It is hardly of etiologic importance, however. In most cases the condition is bilateral and for this reason alone is more suggestive of constitutional than of traumatic factors. Besides, the history of almost all cases fails to include severe trauma. Of great interest in this connection is the case reported by Stören of a family of ten children with osteochondritic joint lesions occurring in the father and four children. Stören's case shows so clearly the importance of a constitutional and hereditary background in the formation of osteochondritic bodies that all attempts to introduce trauma as an etiologic factor seem to be far fetched. Questions of compensation, which will arise in view of the fact that most of the patients are workmen in the prime of life, will have to be considered accordingly, as was done in case 4. As long as nothing is known about the cause of "idiopathic" aseptic necrosis, as long as physicians have only vague ideas concerning the possible duration of a process of reorganization which is hypothecated from the roentgenologic changes, the patient may benefit from the physician's ignorance. In case of doubt and uncertainty, one may decide in the

patient's favor. If, as in case 4, roentgenologic findings contradict causal connection between aseptic necrosis and industrial accident, the claim will have to be considered on the ground that the trauma has occurred in a pathologic skeleton and will have to be rejected in most instances.

Also of great practical importance is the question of hypertrophic arthritis in connection with osteochondritis dissecans. The head of the femur in cases 4 and 6 was enlarged at the time of operation; there were large marginal exostoses, and the synovial tissue was decidedly hypertrophied. The autopsy in case 3, however, showed diminution rather than enlargement of the affected femoral heads. The explanation of this difference is probably as follows: In case 3 the disease was certainly of much longer duration, and accordingly a much greater portion of the head of the femur had been lost by absorption.

Another important factor is the use of the joint. Hypertrophic arthritis does not necessarily complicate the picture of aseptic necrosis. The joint cartilage primarily does not participate in the pathologic process; it will however, become affected secondarily by the deformation of the bony epiphysis (Axhausen's osseous form of arthritis deformans). The deformation, as already pointed out, will be the greater the more the joint is used during the active phases of the organizing process. Hypertrophic arthritis never develops in a joint which is kept at rest. There is no doubt that the patients in cases 4 and 6, laborers, used their hips more than did the patient in case 3, although I had only a scant clinical history in this case. There are two facts, therefore, to explain the relative smallness of the femoral heads in case 3: there was more bone absorption, because of the longer duration of the disease, and the hypertrophic arthritic changes were only mild because of the restriction of function. The enlargement of the head, the mushroom deformity, can be considered as the result of overuse of a diseased joint.

However, there is still another fact which is certainly of importance for the development of arthritic changes. I mentioned in the report of case 6 the hole in the joint cartilage through which detritic material oozed into the free joint cavity with every increase in the intra-articular pressure. A similar oozing must have taken place in case 4, in which there were multiple fractures of the joint cartilage, with a spicule of bone protruding toward the joint cavity at the end of the subchondral fracture space. I also mentioned the constant irritation of the synovial membrane by this seeping of necrotic powdered material into the joint. The reactive hyperplastic changes of the synovial capsule and the active cartilaginous proliferation at the joint margins were certainly due in part at least to this articular irritation.

It may be that such a perforation of the joint cartilage is a "safety valve" in cases of epiphysionecrosis. If the pressure within the subchondral fracture and marrow spaces rises above a certain level by the accumulation of ground-up calcified material, the latter can escape through the hole of the joint cartilage into the joint cavity, thus decreasing the pressure within the bony epiphysis. Exactly the same mechanism was observed by Pich [13] in her case of traumatic Perthes' disease.

Treatment for the patients belonging to the second group is not as simple as for those of the first group. Deformation of the femoral head is usually marked, osteochondritis dissecans being a late complication of reorganization of aseptic necrosis. Physical therapy may temporarily relieve symptoms, but it will not have lasting effect. For advanced and extensive epiphysionecrosis one must consider surgical intervention. No one, however, who has ever seen such a femoral head will think with Mouchet that the removal of the dissected portion is an easy or advisable procedure. As practically the entire joint surface is involved, removal of the necrotic area will deprive the head of the femur of its joint cartilage and will increase and not alleviate the deformity. Only radical procedures can be of help: either arthrodesis or arthroplasty. Arthrodesis is certainly the safer procedure, but it should be resorted to only if the condition is unilateral. I should never recommend arthrodesis for bilateral conditions. One hip is usually more affected and may be the only one that bothers the patient. If this hip should be fused, it is probable that within a short time after the operation the same symptoms which led to the fusion operation would develop in the other hip. I feel, therefore, that arthroplasty is the wiser procedure. I performed it in cases 4 and 6. The result in case 4 at the time of writing, two years after the operation, is gratifying to both the surgeon and the patient. In case 6 the operation was done too recently to permit one to judge the result. The arthroplasty in this case was combined with a wedging out of the greater trochanter according to Albee's technic in order to reconstruct the length of the neck and to overcome the insufficiency of the abductors.

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13. Pich, G.: Histopathologic Study in a Case of Perthes' Disease of Traumatic Origin, Arch. Surg. **33**:603 (Oct.) 1936.

PARTIAL THORACOPLASTY WITHOUT DEFORMATION

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All surgical methods pass through three stages: first, the pioneer stage, during which the surgeon is happy if the operation has been successful, that is to say, if the patient has survived it; then the second stage, in which, the rate of mortality having diminished, the surgeon endeavors to render the operation more efficacious, and finally the third stage, in which he tries to perform an efficacious operation with as little mutilation as possible.

Surgical treatment of pulmonary tuberculosis has already passed the first two stages. It no longer endangers life, and it is efficacious. This is the result of thirty years of continued effort on the part of surgeons all over the world. At present the problem consists in performing the operation without mutilating the patient.

Examination of a patient on whom a routine thoracoplasty has been performed reveals that the deformity he presents is due to three causes: (1) vertical lowering of the scapula with subsequent fall of the shoulder; (2) sinking in of the scapula into the depth, this bone being also projected laterally, and (3) scoliosis, with convexity toward the side on which operation was done. Scoliosis when slight may not be noticed, but when accentuated it may cause considerable deformity.

For a long time it was thought that this deformity might be due to the thoracic collapse; however, close observation of the static condition of the scapular girdle indicates that the latter, essentially leaning on the sternum through the clavicle and attached to the spine by means of the muscles of the scapula, forms a sort of vault under which the thorax is set. It is therefore possible to collapse the apex of the thoracic cavity completely without involving the scapular girdle, provided the muscles are spared as much as possible.

As a matter of fact, the displacement downward of the lower part of the shoulder blade is due to section of the trapezius, the levator scapulae and the rhomboid muscle, which normally suspend this bone. The lateral displacement is due to section of the rhomboid muscles, which allows the scapula to slide outward. The sinking of the scapula

From the American Hospital of Paris.

into the depth of the cavity produced by the thoracoplasty is due to the pull of the collapsed thoracic wall through serratus magnus, since this muscle unites the posterolateral portion of the thorax to the spinal border of the scapula. This sinking is not due to loss of the osseous support of the scapula, as it is still in contact at its angle with the seventh and eighth ribs. On the other hand, the pull of this muscle opposed by the scapula also prevents the collapse from being as complete as it might be. Therefore, whereas the muscles which hold the scapula should be respected by the surgeon, it is important to sever the serratus magnus.

As regards scoliosis, the pathogenesis of this complication has been extensively discussed: Hug [1] in Germany, Bisgard [2] in America and recently Cleveland [3] all have studied the question thoroughly. It is evident that the greater the number of ribs resected, the greater the risk of scoliosis; this, however, is not an absolute rule, and according to our own experience thoracoplasty may be performed without the rectitude of the spine being affected if the integrity of the lateravertebral muscles is preserved, as this important mass can prevent an exaggerated deviation. Important deformities are observed (1) when these muscles have been slashed in an attempt to find the neck of the rib (this method is, we believe, now abandoned by all surgeons) and (2) when the portions of the skeleton into which these muscles are inserted, namely the transverse processes of the vertebrae, have been removed.

It is our opinion that from the orthopedic point of view the removal of the transverse processes of the vertebrae is a mistake. The efficacy of this procedure in treatment of tuberculous lesions is doubtful. Moreover, it has become unnecessary since the introduction of Semb's technic for extrafascial apicolysis, which makes it possible to free the lung from the skeleton. Extrafascial apicolysis is unquestionably an improvement in pulmonary surgery, because, as it includes both lateral and vertical collapses, fewer bones have to be sacrificed than in ordinary thoracoplasty, which produces only a transverse mobilization.

The time is past when surgeons proudly added up the length of the ribs they had resected, happy when the total exceeded 1 meter. At present the surgeon's ambition is to obtain the best possible collapse with the least possible costal resection.

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1. Hug, O.: Thorakoplastik und Skoliose, Ztschr. f. orthop. Chir. (supp.) **42**:1, 1921.

2. Bisgard, J. D.: Thoracogenic Scoliosis: The Influence of Thoracic Disease and Thoracic Operations on the Spine, Arch. Surg. **29**:417 (Sept.) 1934; Skeletal Deformities in Children Resulting from Empyema and Methods of Prevention, J. Thoracic Surg. **6**: 609 (Aug.) 1937.

3. Cleveland, M.: Lateral Curvature of the Spine Following Thoracoplasty in Children, J. Thoracic Surg. **6**:595 (Aug.) 1937.

One may conclude, therefore, that to cause no deformity thoracoplasty should not involve the trapezius muscle, the angular and rhomboid muscles or the latissimus dorsi muscle, since these muscles fix the scapula. In view of this, many authors have proposed a lateral axillary incision which cuts into only the serratus magnus. Such an incision, unfortunately, provides an insufficient opening precisely at the site where an opening is most needed; a simple thoracoplasty by this method is difficult, and Semb's operation could not even be considered.

Whence the interest of muscular dissociation, the possibility of which was demonstrated on the abdomen by McBurney? Picot,[4] of Lausanne, Switzerland, was the first surgeon who tried to operate on the thorax by dissociating the muscular fibers of the trapezius and rhomboideus muscles without cutting the fibers. Picot used a transverse or slightly oblique interscapulovertebral incision which enabled him to perform either an endofascial apicolysis or a small thoracoplasty.

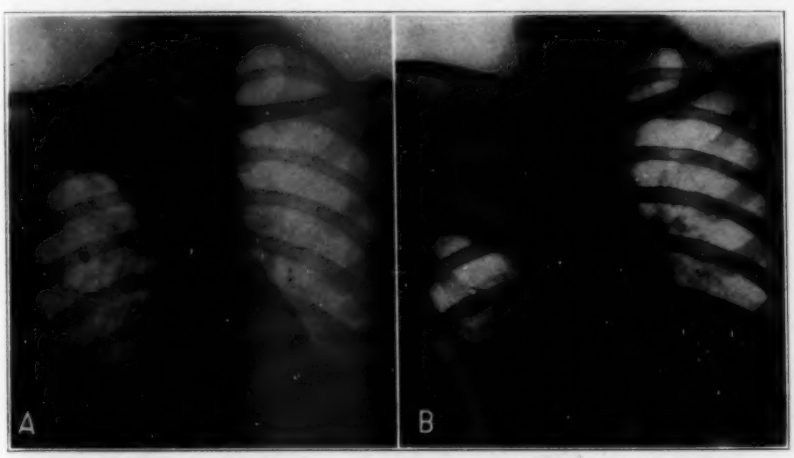

Fig. 1 (case 1).—*A*, cavitation of apex, of two years' duration. A one stage extrafascial apicolysis was performed, with resection of five ribs. *B*, result six months after operation. Cultures of the sputum were sterile, and the patient was apparently cured.

By modifying the direction of Picot's incision and cutting some of the trapezius fibers (the ascending fibers which play no part in fixation of the shoulder) we were able to perform thoracoplasties involving as many as six ribs and to perform extrafascial apicolysis [5]

4. Picot, in Bernou, A., and Fruchaud, H.: Chirurgie de la tuberculose pulmonaire: Indications, techniques, résultats, Paris, Gaston Doin & Cie, 1935.

5. Iselin, M.: L'apicolyse extra-fasciale (méthode de Semb), Presse méd. **45**:1539 (Nov. 3) 1937. Iselin, M., and Dupan, R.: Technique de l'apicolyse extra-fasciale totale, J. de chir. **52**:748 (Dec.) 1938.

under conditions far more favorable than those obtained in making the usual incisions around the scapula.

The cutaneous incision is oblique, starting at the seventh cervical vertebra (the prominent one) and extending as far as 3 cm. below the angle of the scapula. The upper part of the incision does not have to reach the seventh cervical vertebra but starts at 1 cm. from it; if necessary, its lower extremity may be prolonged along the spinal border of the scapula.

Therefore, this incision coincides at its upper extremity with the posterior part of the first rib and at its lower extremity with the anterior part of the first rib. It allows a favorable approach to the most difficult point in surgical treatment of pulmonary tuberculosis: ablation of the first rib, the key of the thoracoplasty.

Fig. 2 (case 1).—Patient one month after operation.

The skin having been incised and freed on each side, the trapezius muscle is dissected between two of its transverse fibers, that is to say, at the level of the upper angle of the scapula. Then, almost perpendicularly, the ascending fibers are cut 1 cm. from their attachment to the bone; the débridement is effected over 4 to 5 cm. Immediately underneath, one finds the rhomboid muscle, the oblique fibers of which are exactly parallel with the incision. One cuts between the muscular fasciae at the middle portion of the wound. Two retractors are placed, and when the scapula is retracted laterally a small portion of the costal grill, usually in the vicinity of the third and fourth ribs, comes into view.

Through a longitudinal incision along its external border, the latero-vertebral muscular mass is separated from the costal plan, and it is then easily retracted as far as the transverse processes of the vertebra by means of Semb's retractors.

The medial aspect of the rib is now exposed. To put the lateral aspect in evidence, the surgeon's assistant pulls on the scapula and stretches the serratus magnus muscle, which is cut so as to put the anterior extremity of the rib within reach. Alexander was wise in insisting on this maneuver.

However, the opening obtained is not considerable. The fourth rib should be carefully disarticulated and resected over 8 to 10 cm. The third rib is then much more easily viewed; it also is resected and disarticulated; the third rib can be resected much more easily than the fourth. Then the second rib appears and is entirely freed and resected. When the second rib has been removed, the first rib appears and, once the serratus magnus and the posterior scalene muscle have been cut, it is viewed from end to end on both superior and inferior aspects.

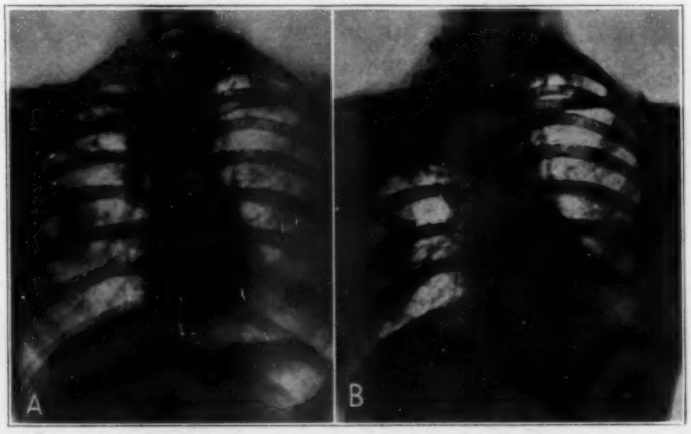

Fig. 3 (case 2).—*A*, extensive cavitation of the right apex of five years' duration. *B*, result six weeks after operation (a one stage extrafascial apicolysis, with resection of five ribs).

The surgeon who has never used this particular incision will be surprised to find that with its use the ribs can be viewed one after the other. However, this is anatomically logical, since when seen from the posterior aspect the first three ribs appear not vertical but horizontal, one before the other. Such an incision fits in with the surgical needs. The nearer one gets to the difficult and dangerous area, the better the view provided, whereas the usual incision around the scapula opens into a sort of well, the bottom of which is deep and inaccessible. Extrafascial apicolysis is much more easily performed with the incision described, since the apex of the lung is exactly in the center of the wound.

Fig. 4 (case 2).—Patient six months later. The sputum was sterile, and the patient was apparently cured.

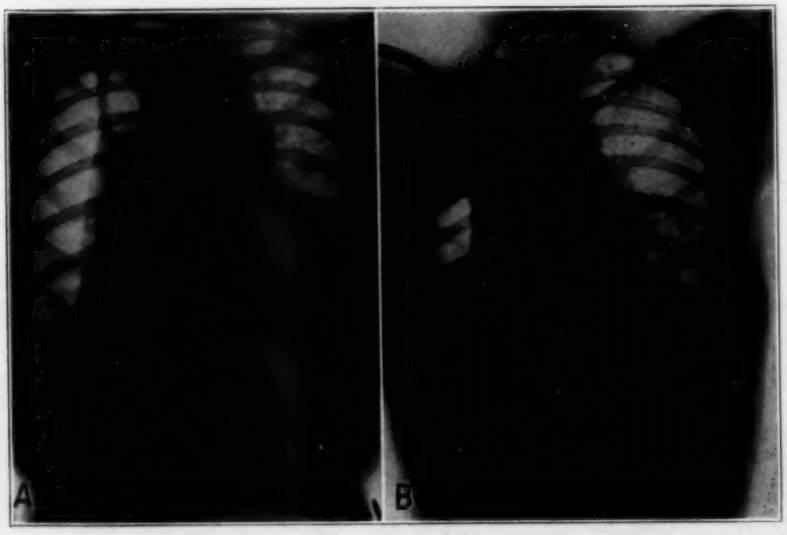

Fig. 5 (case 3).—*A*, extensive cavitation into incomplete artificial pneumothorax. *B*, roentgenogram taken on discharge of the patient, three weeks after the operation. Six months later the sputum was sterile and the patient apparently cured.

Of course, it is necessary to have at one's disposal a set of instruments suitable for the purpose, since the mere introduction of the surgeon's hand into the incision obliterates the entire operative field. Everything has to be done with forceps, even the knots. The compresses must also be handled with forceps. Our equipment, manufactured by Collin, in Paris, and partly inspired by Semb's equipment, is simple. It includes:

1. Two Semb retractors for retracting the laterovertebral mass inward without injuring it.

2. Two strong double-bent retractors, the larger for retracting the scapula outward and the smaller for retracting the trapezius muscle upward. Naturally, one should never retract medially and laterally at

Fig. 6 (case 3).—Patient two weeks after operation (a one stage extrafascial apicolysis, with resection of four ribs).

the same time, as the incision would be too small. For working on the outer and anterior regions, the surgeon uses retractors with a handle; for working medially, the traction is best provided by Semb retractors.

3. Three rugines, one for the outer face, one for the border and one for the deep face of the rib. Each one cuts only at the precise site where cutting is needed, all the remainder of the instrument being blunt. This is the reason for the semicircular shape of the instrument.

4. Brünner's costostome for costostomy. We had the instrument made, however, with a double-bent stem, so that the hand holding it would not hide the incision. Because of this double bending and because of its length, it is possible to push this costostome very far inside and to watch its extremity and know exactly what is being cut.

5. Two spatulas of the type employed by Semb. We do not, however, use his hooks, which we find too large and likely to cause trauma. We had made by Collin two special instruments for this purpose.

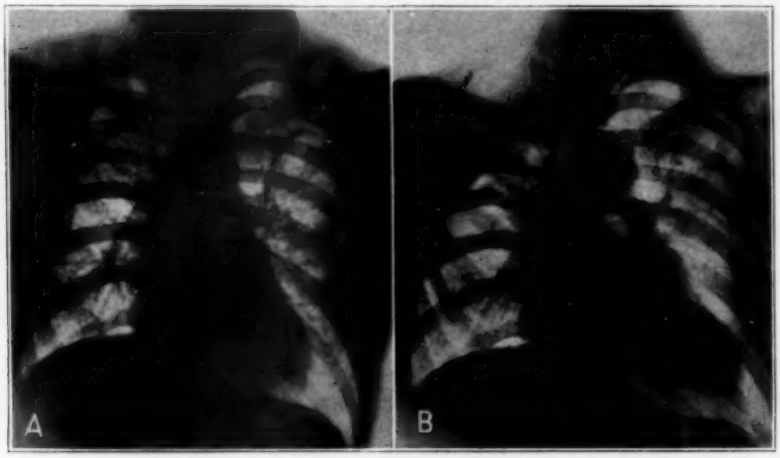

Fig. 7 (case 4).—*A*, huge cavitation of the apex of the right lung of three years' duration. *B*, roentgenogram taken one year after operation (a two stage extrafascial apicolysis with resection of six ribs).

Fig. 8 (case 4).—Patient one year after operation. The sputum was sterile and the patient was apparently cured.

It may seem surprising that the scapula can be so easily retracted in spite of the preservation of its muscles; this is done by putting the patient flat on his stomach and raising the arm, which places the bone in the sagittal plane and entirely disclosed from the thorax. It is maintained in this position by means of a retractor.

It is needless to emphasize the advantages of this incision. It provokes little hemorrhage, and, as the muscle is not cut, it does not cause shock. A surgeon accustomed to this technic can easily resect six ribs if necessary. Reconstruction is extremely simple: the ascending fibers of the trapezius muscle which have been cut must be carefully sutured; in this region the trapezius adheres to the aponeurosis so that one has only to stitch in the latter. The dissociated muscular parts are brought together by means of two sutures, as in McBurney's incision.

The results are excellent. For the past two years we have resorted to this incision for all thoracoplasties and extrafascial apicolyses. The accompanying photographs and roentgenograms show the extraordinary morphologic preservation, in contrast with the considerable degree of thoracic collapse obtained.

APPENDICITIS

WITH ESPECIAL REFERENCE TO PATHOGENESIS, BACTERIOLOGY AND HEALING

WARNER F. BOWERS, M.D.

OMAHA

INTRODUCTION

The thesis that appendicitis in the majority of cases is a form of closed loop obstruction will be developed in this paper. It will be shown that in 80 per cent of all cases in the series the condition was on an obstructive basis and that in 67 per cent an impacted fecalith was the obstructing mechanism. It will be demonstrated that there is a direct correlation between the presence of a fecalith and subsequent development of obstruction with closed loop formation, eventuating in perforation and peritonitis if the obstruction is not overcome by expulsion of the fecalith or release of the obstruction by other means.

As early as 1846 this sequence of events in appendicitis was noted by Volz [1] in his monograph. He reported 46 cases in which such a series of events was observed, and he mentioned five other authors who had seen a similar pathologic picture. (fig. 1). In 1847 Gerlach [2] reported a case in which the fecalith was said to have been as large as a hazelnut. In his epochal paper in 1886 Fitz,[3] of Boston, made similar reference to the high incidence of fecaliths and obstruction, especially in cases of perforation. Pozzi,[4] in 1897, emphasized the fact that in appendicitis the appendix behaves as does any other closed loop. In

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1. Volz, A.: Die durch Kotsteine bedingte Durchbohrung des Wurmfortsatzes, die häufig verkannte Ursache einer gefährlichen Peritonitis un deren Behandlung mit Opium, Carlsruhe, C. F. Müller, 1846.

2. Gerlach, A.: Beobachtung einer tödlicher Peritonitis als Folge einer Perforation des Wurmfortsatzes, Ztschr. f. rat. Med. **6**:12-23, 1847.

3. Fitz, R. H.: Perforating Inflammation of the Vermiform Appendix with Especial Reference to Its Early Diagnosis and Treatment, Am. J. M. Sc. **92**: 321-461, 1886.

4. Pozzi, M. S.: Pathogénie de l'appendicite, Presse méd. **1**:1-4, 1897.

his monograph in 1908 Maalø [5] cited Iverson, Reclus, Roux, Treves and Dieulafoy as saying that appendicitis usually is a sequel to obstruction of the lumen and formation of a closed cavity. Morison and Saint [6] noted the danger of tension gangrene following obstruction of the lumen of a hollow viscus, such as the appendix.

There is much of interest in the history of appendicitis, but it has been well discussed by Deaver,[7] Kelly and Hurdon,[8] Royster,[9] Collins [10] and many others, so that no attempt will be made to cover that phase of the subject here.

THEORIES OF ETIOLOGY

There are seven main theories (Krecke [11]) with regard to the etiology of appendicitis. A critical discussion of each follows.

Fig. 1.—Longitudinally sectioned appendix, demonstrating the distention of the lumen and thinning of the walls seen in appendixes obstructed by an impacted fecalith. This is the typical picture seen when the obstruction has existed long enough for tension gangrene to supervene.

5. Maalø, C. U.: Histopatologiske studier over processus vermiformis, Copenhagen, 1908.

6. Morison, R., and Saint, C. F. M.: An Introduction to Surgery, Baltimore, William Wood & Company, 1935.

7. Deaver, J. B.: Appendicitis, Philadelphia, P. Blakiston's Son & Co., 1896.

8. Kelly, H. A., and Hurdon, E.: The Appendix and Its Diseases, Philadelphia, J. B. Lippincott Company, 1911.

9. Royster, H. A.: Appendicitis, New York, D. Appleton and Company, 1927.

10. Collins, D. C.: Historic Phases of Appendicitis, Ann. Surg. **94**:179-196, 1931.

11. Krecke, A.: Ueber die Ursachen und das Wesen der Appendizitis, München. med. Wchnschr. **80**:299-302, 1933.

1. *Infectious Origin.*—(*a*) Enterogenous: In view of the fact that the dictums of Aschoff have been generally accepted for many years, they will be discussed first. Aschoff [12] stated that infected fecal matter comes to rest in one of the permanent rugations of the appendical mucosa and that owing to stasis the organisms, usually gram-positive diplococci, increase in virulence so that they are able to penetrate the mucosa. A wedge-shaped area of inflammation then develops, and while the main reaction in the distal third of the appendix is mucosal, the organisms spread rapidly up the lymph spaces of the submucosa, so that in the proximal third the serosa is most severely involved. Not simple retention of feces but stagnation of the special content of the appendix is responsible for appendicitis, according to Aschoff, and he stated definitely that in every case acute appendicitis develops on the basis of a local enterogenous infection in an especially susceptible, or "prepared," appendix. Fecaliths, he stated,[13] act only by aiding stasis and retaining bacterial toxins. Aschoff was able to isolate pure strains of a gram-positive diplococcus from the distal third of the appendix, and he concluded that these unsociable organisms, which do not mix with the ordinary fecal flora, are the sole cause of appendicitis, being as specific as the gonococcus or the tubercle bacillus.

There are a number of serious objections to the views of Aschoff. First, no one has ever been able to confirm his statement that the appendix contains a special type of flora unmixed with fecal organisms. In Europe diplococci apparently form a prominent component of the human fecal flora, but in the United States they are comparatively uncommon, except in laboratory animals. Second, no one has ever been able to find the wedge-shaped area of primary infection, and Aschoff himself said that unfortunately he has not been able to demonstrate it on section. Furthermore, it never has been shown that stasis of organisms increases their virulence; rather, it has been proved that stasis weakens a strain because of the development of bacteriophage and degenerative forms. Moreover, it has been shown that the best way to increase the virulence of a bacterial strain is by rapid passage through a series of laboratory animals. It cannot be shown that the inflammation spreads proximally from the site of origin, as it should if Aschoff's theory is correct. In fact, in this series the inflammation was always distal to the point of obstruction and faded off to a normal condition near the base, unless the obstruction was at the base, in which

12. Aschoff, L.: Pathogenesis und Aetiologie des Appendicitis, Ergebn. d. inn. Med. u. Kinderh. **9**:1-30, 1912; Appendicitis: Its Aetiology and Pathology, translated by G. C. Pether, London, Constable & Co., Ltd., 1932.

13. Aschoff, L.: Ueber die Bedeutung des Kotsteines in der Aetiologie der Epityphlitis, Med. Klin. **24**:587, 1905.

instance the entire organ was involved. If appendicitis is a bacterial disease bacteria should be present in the tissues at an early stage. Actually, it will be shown that in only 20 per cent of cases of acute appendicitis are bacteria present in the tissues, whereas the incidence increases to 60 per cent in the gangrenous specimens. Thus, if the organisms appear late in the course of the disease, or not at all, they cannot logically be assumed to play an important etiologic role. Bacterial toxins need not be invoked as a cause of inflammation, for it can be shown that appendical inflammation will develop in a sterile appendix as a result of osmotic imbalance (Bowers [14]). It can be shown further [15] that in a closed loop of the appendix with complete retention of bacteria and toxins no inflammatory changes occur unless distention of the loop supervenes. According to Aschoff, gangrene develops on the basis of vascular thrombosis, but if this were true there would be no distention of the lumen with thinning of the walls. In all cases of obstruction in this series the lumen was dilated and the wall was thinned,

TABLE 1.—*Observations in a Case of Obstructive Appendicitis* *

Region	Gross Changes	Fecalith	Wall	Lumen	Reaction in Sections	Results of Gram Stain
Tip.....	Gangrene	.....	Thin	Distended	Extreme	Bacteria in mucosa
Midzone.....	Gangrene	Impacted	Thin	Occluded	Some	Negative
Base.....	Acute	.....	Normal	Normal	Slight	Negative

* The inflammation is severest distal to the point of obstruction. Proximally the lumen is normal, and the walls of the appendix show slight reaction. This would not be true if the dictums of Aschoff were correct.

owing to distention. There were few instances of gangrene without obstruction, but in these cases there was no distention or thinning. The walls were thick and soggy owing to accumulation of inflammatory exudate. In the animal series,[15] gangrene of the cecal appendage due to vascular damage was not accompanied by thinning or distention.

The objections to Aschoff's views are demonstrated in the data relative to a typical clinical case (table 1). According to the other theory of the enterogenous infectious origin of appendicitis, swallowed organisms from foci in the nose and throat set up an inflammatory process in the appendix. In support of this view, similar organisms are said to have been isolated from the throat and from the appendix, but this does not prove their pathogenicity, nor is it remarkable that organisms which are constantly being swallowed might be cultured from

14. Bowers, W. F.: Role of Distention in the Genesis of Acute Inflammation of Hollow Viscera, Am. J. M. Sc. **194**:205-214, 1937.

15. Wangensteen, O. H., and Bowers, W. F.: Significance of the Obstructive Factor in the Genesis of Acute Appendicitis: An Experimental Study, Arch. Surg. **34**:496-526 (March) 1937.

any part of the intestinal tract. It also has been argued that the prevalence of dental caries and sinusitis explains the high incidence of appendicitis, but this is as fallacious as the idea that the condition is due to a tonsillar focus.

(*b*) Hematogenous: According to this theory, the appendix serves as an abdominal tonsil and filters organisms out of the blood stream. These organisms are assumed to enter the blood stream from the region of the tonsil. It has even been stated that bacteria in the blood stream electively localize in certain organs. This, it seems, carries the idea of the bacterial origin of disease a bit too far. These points will be elaborated under subsequent captions. Suffice it to say here that no investigator has yet been able to isolate organisms from the blood stream in cases of appendicitis with any degree of frequency. Many series of cases have been reported, but the incidence of blood cultures yielding bacteria is negligible. In 1 case in this series a blood culture contained Bacillus coli. The patient had otitis media and mastoiditis with sinus thrombosis caused by this organism, but the bacteremia was secondary to perforation and generalized peritonitis. The patient died one month after appendectomy.

2. *Neuroangiospastic Origin.*—Ricker concluded that gangrene occurs in appendicitis much earlier than can be accounted for on an infectious basis, and he therefore postulated the theory of vasospasm. He stated that appendicitis is comparable to Raynaud's disease and that gangrene develops because of ischemia of the appendix. This theory has been violently attacked by Aschoff, and, indeed, the finding of a pale, bloodless, gangrenous appendix at operation must be a rare occurrence. The usual appearance is one of turgescence and venous congestion with actual hemorrhage into the tissues. The theory of Ricker is not borne out by observation of clinical cases.

3. *Endemic Origin.*—Familial and institutional outbreaks of appendicitis have been reported, and the question of contagion also has been raised. These "epidemics" are more apparent than real, however, and it will be shown subsequently that the incidence of appendicitis is fairly constant, there being no seasonal variation if observations are carried on over a long period. It is thought that endemic and familial outbreaks are best accounted for on the basis of similar faulty diet or familial poor anatomic arrangement of the appendix, as will be mentioned later.

4. *Dietary Origin.*—The fact that there are so few cases of appendicitis among some peoples, such as the Arabs, the aboriginal Negroes, the Turks, the Persians and the Dutch, has led to the theory that appendicitis is a result of modern diet. It has been reported that

there were but 2 persons with appendicitis among 86,000 clinic patients seen in Tientsin, China. Bearing out the idea of the importance of diet is the fact that in the small series of cases reported here gangrenous appendixes occurred in 2 Chinese students. One of the appendixes was obstructed by a fecalith. Pales [16] found a low incidence of appendicitis among South African natives, associated with a high incidence of a funnel-shaped appendicocecal junction. There may be a similar anatomic explanation for the low incidence of appendicitis in other races. Murray [17] quoted Williams as saying that as a result of beef and mutton fats in the diet calcium soaps are formed in the walls of the appendix. It has been asserted that these insoluble soaps may form a complete ring and produce various complications. It is difficult to see, however, why this deposit should be limited to the appendix. How much more serious such a ring of soap would be in the small intestine! Murray attempted to show that appendicitis develops in wild animals maintained in captivity and cited the low incidence of the disease in the so-called primitive races. Short [18] also mentioned the effect of civilization in causing appendicitis in captive higher apes. The flaw in this theory is that one has no means of knowing what are the usual causes of death among apes in their native jungles. The increased use of iron rollers in grinding grain for flour has been suggested as a cause of appendicitis. It is said to lead to a decrease in cellulose in the diet, with consequent development of constipation, increase in virulence of organisms and appendicitis. As will be shown later, however, rather large amounts of cellulose and vegetable fibers actually are found in the obstructing fecaliths. It seems from this that a decrease in intake of cellulose might reduce the number of fecaliths, the cellulose often acting as a nidus about which the fecalith forms. Appendicitis has been attributed to the increased use of food preservatives and the higher percentage of meat ingested. Some significance may be attached to this statement, as it has been shown by Wilkie [19] that closed loops containing protein material rupture much earlier than others because of rapid putrefaction and formation of gas. Egdahl [20] has shown that the incidence of appendicitis in the Filipino and Puerto Rican units of the United States Army is correlated with

16. Pales, L.: Appendice et appendicite chez le noir en Afrique equatorial française, Ann. d'anat. path. **11**:563-583, 1934.

17. Murray, R. W.: Geographical Distribution of Appendicitis, Lancet **2**:227-230, 1914.

18. Short, A. R.: Causation of Appendicitis, Brit. J. Surg. **8**:171-188, 1920.

19. Wilkie, D. P. D.: Acute Appendicitis and Acute Appendicular Obstruction, Brit. M. J. **2**:959-962, 1914.

20. Egdahl, A.: Some Etiological Factors in Acute Appendicitis, Mil. Surgeon **73**:61-69, 1933.

the incidence of beriberi. He has shown also that the incidence of appendicitis is low when these troops are fed on their native diet but increases markedly when they are given the same diet as white troops. Here, again, the factor of constipation and fecalith formation may be important. Egdahl also stated that in student health services there is a significant grouping of cases after the Thanksgiving and Christmas holidays, on a basis of dietary indiscretions. It is well known among pediatricians that children frequently have attacks of acute appendicitis after a particularly heavy meal. This tendency is based on the fact that the increased secretory and peristaltic activity may initiate a pressure-distention mechanism in the appendix. The use of water closets instead of the squatting position in defecation has been said to increase the incidence of appendicitis, on the assumption that the new position favors constipation. Mercier, in scorn at these peculiar suggestions, suggested the abandoment of wig wearing as the cause of appendicitis.

5. *Traumatic Origin.*—Shutkin and Wetzler [21] concluded that traumatic appendicitis may occur in some cases, and there seems to be a logical explanation for its pathogenesis. The appendix may be crushed against the ilium or the spine, with resulting infarction or gangrene. Wangensteen and Bowers [15] have shown experimentally that vigorous pinching of the appendix is followed by inflammatory changes. This type of gangrene is not accompanied by distention or thinning of the walls of the appendix. The appendix may be overdistended suddenly by a blow on the abdominal wall so that it is actually ruptured, or it may be so severely stretched that rents in the mucosa occur and infection develops. If the appendix happens to contain a fecalith, trauma may impact the fecalith or edema may so reduce the diameter of the lumen that a small fecalith will occlude it. In either event a closed loop is formed, with all of its potentialities. There is no doubt that trauma may cause appendicitis in some cases. In this series, 1 patient gave a history of having been kicked in the abdomen on the day previous to the attack. The appendix was gangrenous and was obstructed by a fecalith. The significance of the trauma cannot be evaluated.

6. *Foreign Body Origin.*—Monographs on appendicitis have listed lead shot, pins, bristles, various types of seeds, spicules of bone, enamel from cooking vessels and many other types of foreign bodies as having been seen in the appendix in addition to fecaliths. One theory is that a foreign body, by its mere presence in the lumen, sets

21. Shutkin, M. W., and Wetzler, S. H.: Traumatic Appendicitis, Am. J. Surg. **31**:514-520, 1936.

up an acute inflammatory reaction and erodes through the wall. That this is not necessarily true is shown by the fact that foreign bodies often are seen in the appendix during routine autopsies. The deciding factor in the development of inflammation is whether the foreign body occludes the lumen, forming a closed loop. Foreign bodies may cause appendicitis in one of two ways: They may actually erode or pierce the wall, introducing infection, or they may occlude the lumen and form a closed loop. Formerly it was thought that a foreign body acted by causing stagnation and allowing increase in virulence of the retained organisms. It is now known that the consequent distention of the closed loop rather than retention of bacteria or their products causes appendicitis.

7. *Mechanical Origin.*—That mechanical factors may be of great importance in the causation of appendicitis is not a recent idea. It was advocated in 1897 by Pozzi,[4] who accredited the original concept to Dieulafoy. Pozzi stressed the mechanical effect of the valve of Gerlach in converting the appendix into a closed loop. Many experiments have been performed in which various foreign bodies were placed in the appendix, but the dictums of Aschoff have been so generally accepted that whenever acute inflammatory changes resulted it was said that the mechanical factors had caused retention of bacteria with consequent increase in virulence. These experimental results will be discussed under another caption, and the probable course of events in the genesis of appendicitis from the mechanical standpoint will be elaborated later.

Summary.—There are only two distinct theories of the causation of appendicitis, the others being related merely to contributing factors. Infection and obstruction are the two etiologic agents, the latter operating in the majority of cases. Trauma may set either mechanism in motion; while diet and foreign bodies may be the initial cause of obstruction. As will be shown later, bacteria enter the picture even in cases in which the condition is due to obstruction, for they may cause increased damage to the tissues after primary vascular occlusion from obstruction. If it were not for the presence of bacteria, rupture of a closed loop of appendix would be harmless; therefore, although obstruction is the cause of appendicitis in most cases, bacteria are responsible for most of the fatalities.

STATEMENT OF THE PROBLEM

1. *Approach.*—Wangensteen and I [15] have shown in a large experimental series that obstruction and infection are the two most important factors in producing inflammatory changes in the cecal appendage of the dog. We showed, further, that increase in intraluminal pressure

is the most important factor in the genesis of acute inflammation. Intraluminal pressures of 6 and 15 cm. of water maintained for six to eighteen hour periods caused acute inflammation which progressed to gangrene in the longer experiments. I have shown [14] that acute inflammation develops in hollow viscera owing to obstruction and to hydraulic or osmotic imbalance even in the complete absence of the factor of infection. Maintained distention of the sterile renal pelvis or of the eye, for example, has produced all the changes associated with acute inflammation.

2. *Purpose of This Study.*—These and other observations make pertinent this investigation, in which an attempt is made to determine whether the obstructive factor is present in clinical appendicitis and in what proportion of cases such a mechanism operates. It also is proposed to explain the pathogenesis of appendicitis and to evaluate the importance of bacteria in this process. Fecaliths are studied from the standpoint of their origin and their chemical composition. Other etiologic and pathologic factors in appendicitis are investigated from analysis of clinical cases.

MATERIAL AND METHOD

The material consisted of all the appendixes removed at the Minneapolis General Hospital during 1935, together with a selected group of autopsy specimens, and all the appendixes removed at the University Hospitals in 1936. This material included a selected group of appendixes removed incidentally during some other surgical or gynecologic procedure. There were 485 specimens in the entire series, and they were divided into appropriate groups, depending on the pathologic picture.

All the specimens were fixed in a 10 per cent concentration of solution of formaldehyde U. S. P., in a large, flat dish, and after twenty-four hours were "bivalved" longitudinally in order to study the incidence of obstruction of the lumen due to fecaliths, strictures, kinks and other mechanical agencies. The specimens then were sectioned longitudinally, and these sections, through the entire length of the organ, were stained with hematoxylin and eosin and by the Gram-Weigert method for bacteria in the tissues. In one group sections also were stained by the azocarmine technic in order to study the process of fibrosis in healing. An attempt was made to correlate the details of the history, physical findings and laboratory data with the pathologic picture in each instance. The clinical series were analyzed statistically. Various special procedures were employed in some groups, and these will be described under subsequent captions.

ANATOMY

1. *Appendical Musculature.*—The surgeon usually thinks of the appendix as a narrow, blind pouch which readily may become converted into a closed loop by a variety of factors, such as appendicoliths, inspissated contents of the lumen, organic strictures, embryonic kinks, neuromuscular disturbances or abnormality of the basal valve of Gerlach.

That there are anatomic factors which predispose to the development of a closed loop has been shown by Westphal,[22] who demonstrated that the appendicular musculature is normally heaviest and most active at the base. He showed on roentgen examination that peristalsis usually begins at the base and most often progresses toward the tip, instead of attempting to empty the organ. He also showed that the lumen is bulbous, which makes difficult the egress of material which has found its way into the lumen. This point is important in understanding why fecaliths which have been in the appendix for years suddenly become impacted near the base, owing to some strong peristaltic stimulus or to their slow increase in size by accretion. Wood,[23] on the other hand, stated that distal dilatation of the lumen is a characteristic roentgenographic finding in the pathologic appendix.

2. *Appendicocecal Junction.*—It is known that of the several types of appendicocecal junction described by Treves [24] the infantile, or funnel, form is least likely to allow obstruction at the base. The significance of this fact has been demonstrated by Pales [16] who showed that the incidence of acute appendicitis among African natives is 0.03 per cent and who observed in a large series of autopsies that the conical type of implantation of the appendix into the cecum predominates. Treves described four anatomic types of appendical origin from the cecum. 1. In the fetal type the appendix arises from the lowest point of the cecal apex in a funnel-shaped manner. Sprengel [25] observed this type of origin in 25 per cent of cases, but Monrad,[26] in examining appendixes of children, found it only in patients under 3 years of age. 2. In the transitional type the appendix springs from the cecal apex but is without the funnel-shaped base. 3. In another type the appendix arises just medial to the cecal apex. 4. In the fourth type the appendix arises from the most medial portion of the cecal apex, posterior to the ileocecal valve. Wangensteen, Buirge, Dennis and Ritchie [27] classified 262 appendixes according to Treves' types and observed type 1 in 40 per cent, type 2 in 2 per cent, type 3 in 52 per cent and type 4 in 6 per cent. When the specimens were divided according to the age of the patient, they found that 67 per cent of the appendixes of patients up to 11 years of age were of type 1. They studied 477 appendixes with

22. Westphal, K.: Appendizitis und Kotstein als Folge gestörter Appendixfunktion, Deutsche med. Wchnschr. **60**:499-504 and 600-604, 1934.

23. Wood, F. G.: Radiology of the Appendix, Brit. M. J. **1**:640-642, 1935.

24. Treves, F.: Lectures on the Anatomy of the Intestinal Canal and Peritoneum in Man, Brit. M. J. **1**:415, 470, 527 and 580, 1885.

25. Sprengel, F.: Appendicitis, in Billroth, T., and Luecke, G.: Deutsche Chirurgie, Stuttgart, Ferdinand Enke, 1906, no. 117.

26. Monrad, cited by Maaløe.[5]

27. Wangensteen, O. H.; Buirge, R. E.; Dennis, C., and Ritchie, W. P.: Studies in the Etiology of Acute Appendicitis, Ann. Surg. **106**:910-942, 1937.

reference to the diameter of the cecal orifice and found that 0.4 per cent of the orifices were more than 15 mm. in diameter, 17 per cent varied between 10 and 15 mm., 2 per cent between 6 and 10 mm., 32 per cent between 4 and 6 mm., 1 per cent between 2 and 4 mm. and 44 per cent between 0.5 and 2 mm.; 2 per cent were 0.5 mm. in diameter. The cecal orifice was round in 23 per cent, oval in 32 per cent, irregular in 3 per cent, crescentic in 27 per cent and slitlike in 13 per cent.

3. *Appendical Lymphoid Tissue.*—The role of lymphoid tissue as a defense against acute appendicitis has been greatly overemphasized. Berry [28] has shown that the fetal appendix contains no lymphoid follicles. According to him, lymphoid tissue appears in fourteen days, functional lymph nodes are present in six weeks and the number of follicles increases until the age of 20 years, when decrease begins. By the age of 60 there are only traces of lymphoid tissue. This cycle of development and atrophy closely approximates the curve for the age incidence of appendicitis, so that at the time when there is the greatest amount of lymphoid tissue the incidence of appendicitis is at its peak. My observations on appendical lymphoid tissue in patients ranging from premature infants to octogenarians parallel those of Berry.

4. *Mucosal Fold of Gerlach.*—In 1847, Gerlach [2] described a mucosal fold at the appendicocecal junction, which he observed to be present in 3 of 9 cases. He stated that this valve promotes stagnation of contents and the formation of fecaliths. Treves stated that the fold or some modification of it is usually present. The presence of this fold has long been denied by anatomists, but Wangensteen, Buirge and others,[27] in studies of the microscopic anatomy of the appendix, observed this fold to be definite in most instances. Of 526 specimens they observed the mucosal fold in 81.5 per cent. This fold completely obscured the cecal orifice of the appendix in 11 per cent, partially concealed it in 15 per cent and failed to cover it at all in 74 per cent. That the mucosal fold cannot function as a sphincter was shown by the fact that in specimens from adult patients it never contained muscle tissue.

ETIOLOGIC FACTORS

1. *Incidence of Appendicitis.*—The 485 cases in this series have been divided into the following groups for study and classification:

	Acute Appendicitis	Gangrene	Perforative Appendicitis	Appendectomy After Interval	Appendical Colic	Parasites	Gynecologic Group	Autopsy Material
Minneapolis General Hospital	49	20	34	16	5	5	29	23
University Hospitals	43	57	4	131	0	8	33	0
Total	92	77	38	147	5	13	62	23

28. Berry, R. J. A.: Vermiform Appendix of Man: Structural Changes Therein Coincident with Age, J. Anat. & Physiol. **40**:246-256, 1905.

The group of cases of colic includes those in which there were clinical signs of acute appendicitis and the specimens showed evidence of obstruction but microscopic sections showed no inflammation. The gynecologic group includes all specimens removed incidentally during a pelvic surgical procedure.

The difference in the number of cases of perforation of the appendix in the two series is explained by the difference in policy at the two institutions. At the Minneapolis General Hospital all patients with appendicitis are operated on immediately, even in the presence of generalized peritonitis, unless there are signs of a localizing abscess with regression of symptoms. At the University Hospitals, on the other hand, in any case of appendicitis in which perforation and peritonitis are diagnosed a conservative regimen is followed. This consists of duodenal siphonage through an inlying nasal catheter, abdominal hot packs and peroral administration of fluids. Appendectomy is performed six to eight weeks later; cases of this kind, therefore, fall into the "interval" classification. In the student health service at the University, patients with perforated appendixes are operated on, and this accounts for the cases of perforation in the University series.

2. *Age Incidence.*—The average age of the patients with acute appendicitis in this series was 22 years. The average age, expressed in years, for the various groups was as follows:

	Acute Appendicitis	Gangrene	Perforative Appendicitis	Appendectomy After Interval
Minneapolis General Hospital	20	26	27	19
University Hospitals	20	23	17	20

The difference in age in the cases of perforation of the appendix at the two institutions is explained by the fact that at the University Hospitals patients in whose cases perforation is suspected are operated on only in the student health service. This gives a lower average age than the series from a municipal hospital.

TABLE 2.—*Spread of the Age Incidence, Expressed in Years*

	University Hospitals Series	General Hospital Series
Acute appendicitis		
Age of youngest patient	2	5
Age of oldest patient	69	56
Gangrene		
Age of youngest patient	5	8
Age of oldest patient	58	55
Perforative appendicitis*		
Age of youngest patient	15	6
Age of oldest patient	19	83
Interval appendectomy		
Age of youngest patient	4	11
Age of oldest patient	62	52

* The short spread of the age incidence in the group of patients with perforative appendicitis at the University Hospitals is due to the fact that these patients were in the student health service, no patient with perforative appendicitis being operated on in the general surgical service.

In comparing the data for the obstructive and those for the nonobstructive types, it was found that at the Minneapolis General Hospital the average age was identical for the two types, while at the University Hospitals the patients with obstructive appendicitis were 6 years older on an average than those with the nonobstructive type. The patients in the entire series were distributed according to age groups, as follows:

	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 Up
Minneapolis General Hospital	8	42	29	5	1	7	3	0	2
University Hospitals	4	53	20	10	1	5	1	0	0
Average	6	47	24	7	1	6	2	0	1

Similar charts of the age distribution were made for the cases of obstructive appendicitis in the two series. These were found to correspond exactly to the age distribution for the entire series. The youngest patients in whom obstruction by a fecalith was found were a boy aged 3 years in the University series and a girl aged 5 years in the Minneapolis General Hospital series.

It seems to be well recognized that appendicitis is chiefly a disease of childhood and early adult life. The average age mentioned by Tasche and Spano [29] was 22 years; that given by MacCarty [30] was 23 years, and that given by Burgess [31] was 26 years. These figures are comparable with the average age of 22 years in this series.

3. *Sex Incidence.*—Tasche and Spano [29] reported that 61 per cent of the patients with acute appendicitis in the University Hospitals series were males. There were 67 per cent of males in this series. The incidence for males among the groups was as follows:

	Acute Appendicitis	Gangrene	Perforative Appendicitis	Appendectomy After Interval	Parasites
	Cases	Cases	Cases	Cases	
Minneapolis General Hospital	29 (59%)	11 (55%)	25 (73%)	11 (71%)	0
University Hospitals	17 (41%)	41 (73%)	4 (100%)	47 (30%)	0
Average	50%	64%	86%	53%	0

In the group of patients with the obstructive type 58 per cent were males, and in the group with the nonobstructive type, 56 per cent were males. No satisfactory explanation for this preponderance of males ever has been advanced, nor does the phenomenon of obstruction offer any explanation.

4. *Seasonal Variation.*—Stone,[32] Tasche and Spano [29] and most other authors have stated that there is a higher incidence of appendicitis

29. Tasche, L. W., and Spano, J. P.: Analysis of Seven Hundred Consecutive Appendectomies, Ann. Surg. **94**:899-909, 1931.

30. MacCarty, cited by Tasche and Spano.[29]

31. Burgess, A. H.: A Clinical Lecture on an Analysis of Five Hundred Consecutive Operations for Acute Appendicitis, Brit. M. J. **1**:415-418, 1912.

32. Stone, C. S., Jr.: Acute Appendicitis in Children, Arch. Surg. **30**:346-356 (Feb.) 1935.

in the summer. In explanation of this statement it usually is said that there is a higher incidence of infections of the upper respiratory tract and gastrointestinal upsets at this time of year. If appendicitis is an obstructive phenomenon, there is no apparent reason why there should be a seasonal variation. This matter has been subjected to the following investigation. In a study of the incidence of acute appendicitis at the Minneapolis General Hospital (a large municipal charity hospital) over an eight year period, 1928 through 1935, it was found that the curve for the monthly distribution was practically a straight line, the greatest variation between any two months for this period being 2.5 cases. This does not favor a bacterial origin of appendicitis, but is in accord with the theory of an obstructive origin.

5. *Familial Tendencies and Epidemiology.*—In this series no familial relation has been noted. However, from time to time the idea that appendicitis is a contagious disease has appeared in the literature. Fonio [33] stated that he observed 6 cases of the disease in one family and naively added that the total really was 8 if one wished to count a niece and a nephew. He mentioned another family in which there were 6 cases in five years; this would give the disease a rather long incubation period. Fonio and Rieder [34] went further and stated that in 49 per cent of a series of 667 cases they were able to establish a history of contact with patients having appendicitis. The fact that no hospital has ever found it necessary to isolate patients with appendicitis casts grave doubt on the infectious nature of the disease, and the interval between the occurrence of the condition in the same family is much too long to be explained on the basis of contagion. There is no doubt that some families show a greater incidence than others, but this does not prove the theory of infectious origin. The most logical explanation is that there is a similar poor anatomic arrangement in the members of a family or that the family diet is one which favors constipation and formation of fecaliths.

6. *Association with Acute Exanthems.*—In this series a patient with measles was operated on for appendicitis as an emergency procedure, but the appendix was grossly normal; on section the lumen was entirely obliterated, the tissue was sterile and there were no signs of acute inflammation. In another case a patient had measles three days after an appendectomy. The specimen in this case showed no acute changes, but there was some fibrosis with lymphocytic infiltration, indicating previous attacks. In 3 cases scarlet fever developed within the first

33. Fonio, A.: Die Blinddarmentzündung, ihre infectiöse Ursache und ihr endemisches Vorkommen, Schweiz. med. Wchnschr. **53**:947-954, 1923.

34. Fonio, A., and Rieder: Zur Frage der Kontagionsmöglichkeit des Appendicitis, Schweiz. med. Wchnschr. **58**:597-608, 1928.

few postoperative days. The specimens were acutely inflamed or gangrenous but showed no changes which distinguished them from those usually seen in cases of severe appendicitis. One patient had scarlet fever twenty-four hours after appendectomy. The appendix was acutely inflamed; the lumen was distended, and the walls were thinned as in the cases of obstruction, but no definite mechanism of obstruction could be demonstrated. Another patient had scarlet fever seven days after appendectomy. The appendix was gangrenous, and the lumen was obstructed by a fecalith. In the other patient scarlet fever developed eight days after removal of a perforated appendix. The specimen showed evidences of intraluminal pressure and distention, but no definite mechanism of obstruction could be demonstrated. One specimen was obtained post mortem from a girl who had died of scarlet fever. The appendix was normal on microscopic section except for masses of blood pigment deposited around the lymphoid follicles. These masses probably represented the residual signs of hemorrhage into the lymph follicles. Obstruction to the lumen apparently had not taken place, and the tissues did not show the presence of bacteria. In the entire series reported here, the incidence of colds or sore throats immediately preceding the onset of acute appendicitis was only 4.5 per cent.

The literature is full of references to the association of acute appendicitis with acute tonsillitis, infections of the upper respiratory tract, scarlet fever, measles and mumps, but the exact relation is not yet clear. Many of the older writers, including Adrian,[35] have simply stated that such a relation exists. Anderson,[36] Equen [37] and many others have cited outbreaks of appendicitis accompanying epidemics of tonsillitis or so-called "intestinal flu." An analogy between the tonsil and the appendix usually is inferred by these authors. It now is fairly well recognized by most pediatricians that the abdominal symptoms accompanying infections of the upper respiratory tract are on the basis of mesenteric lymphadenitis (Goldberg and Nathanson [38]) rather than of appendicitis. The lymphoid tissue of the appendix may, however, enter into the general reaction of lymphoid tissue to infection and may even bring about appendical obstruction due to the swelling of the

35. Adrian, C.: Die Appendicitis als Folge einer Allgemeinerkrankung klinisches und experimentelles, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **7**:407-445, 1901.

36. Anderson, H. B.: Appendicitis as a Sequel of Tonsillitis, Am. J. M. Sc. **150**:541-548, 1915.

37. Equen, M.: Appendicitis Following Tonsillectomy: A Clinical Study, Tr. Sect. Laryng., Otol. & Rhin., A. M. A., 1932, pp. 130-137.

38. Goldberg, S. L., and Nathanson, I. T.: Acute Mesenteric Lymphadenitis. Am. J. Surg. **25**:35-40, 1934.

follicles. This is the probable cause of appendicitis in the cases of this series in which the condition preceded clinical scarlet fever. Pribam [39] postulated a lymphangitic form of appendicitis and stated that swallowed organisms from the tonsils cause diffuse cecitis, ileitis, appendicitis and mesenteric adenitis. He concluded that the organism is a streptococcus. Tonsillectomy is said to cure the condition by removing the focus.

It frequently is stated that the acute exanthems predispose to acute appendicitis. According to Hudson and Krakower,[40] there have been reported 40 cases of appendicitis occurring during an attack of measles, and according to Donnelly and Oldham [41] in 5 cases appendicitis accompanied mumps. Tasche and Spano [29] reported a 6 per cent incidence of infection of the upper respiratory tract preceding an attack of acute appendicitis, but this is somewhat higher than the incidence of 4.5 per cent reported here.

7. *Relation to Weather.*—Hagentorn [42] worked out an ingenious idea. He reasoned that since drying inhibits bacterial growth and humidity favors it, wet weather should be accompanied by a higher incidence of infections. He then argued that in wet weather the tonsillar organisms should become more virulent and when swallowed ought readily to set up an acute appendical infection. He plotted case records against barometric readings and atmospheric temperature, but unfortunately his theory was not borne out.

8. *Incidence of Parasites.*—In this series there was an incidence of pinworms in 3 per cent of cases, and the average age of the patients was 17 years. In 100 per cent of cases these parasites were found in females. Pinworms often were the central nidus about which a fecalith had formed, but there were always other parasites free in the lumen. In no case could the parasites be seen to penetrate the appendical wall, but artefacts in lymphoid follicles often gave the appearance of parasitic invasion. Clinically, the condition in these cases was diagnosed from the history, physical examination and laboratory findings as acute appendicitis of mild type, but on section the appendixes were normal or merely showed evidence of previous attacks. There were obliteration

39. Pribam, B. O.: Nabelkolik, lymphangitische Form der Appendizitis und Lymphangitis mesenterialis, München. med. Wchnschr. **82**:942-944, 1935.

40. Hudson, H. W., and Krakower, C.: Acute Appendicitis and Measles, New England J. Med. **215**:59-64, 1936.

41. Donnelly, J., and Oldham, J. B.: Mumps and Appendicitis, Brit. M. J. **1**:98-99, 1933.

42. Hagentorn, A.: Einige Bemerkungen zur Aetiologie der Appendizitis, besonders ihrer Wellerungsabhängigkeit, München. med. Wchnschr. **80**:613-614. 1933.

of the tip in 20 per cent of cases, evidence of obstruction in 100 per cent and bacteria in the tissues in 40 per cent. The last observation probably is correlated with the fact that there was distention of the lumen in every case.

The pinworm is the parasite most frequently seen in the appendix. Warwick [43] presented the following data from a series of 2,344 appendixes. The total incidence of pinworms was 2 per cent, and there were no characteristically distinguishing symptoms. The average age of the patients was 18 years, and the parasites were found in females in 93 per cent of the cases. There was no evidence that the parasites had penetrated the tissues except as a postmortem phenomenon.

9. *Previous Attacks.*—It is significant to note that as the severity of the disease process increases the history of previous attacks becomes less frequent, because the seriously ill patients are subjected to appendectomy, whereas in patients with mild appendicitis the process may spontaneously subside many times before a physician is consulted. In this series there was a history of previous attacks in 38 per cent of cases, exclusive of the group in which appendectomy was performed after an interval. The history of previous attacks among the various groups was as follows:

	Acute Appendicitis		Gangrene		Perforative Appendicitis		Appendectomy After Interval		Appendical Colic	
	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
Minneapolis General Hospital	25	51	7	38	10	30	13	81	3	60
University Hospitals	22	51	25	45	1	25	131	100		
Average		51		41		27		90		60

There was a history of previous attacks in 36 per cent of the cases of obstruction as compared with 57 per cent of the cases in which obstruction was not present. This also is a significant observation, indicating that in appendicitis due to obstruction there is less tendency to spontaneous recovery without operation.

In Stone's [32] series there was a history of previous attacks in only 24 per cent of cases. Tasche and Spano [29] reported an incidence of previous attacks of 57 per cent, but their figures included cases in which the patient was treated conservatively after perforation and returned for operation later.

PHYSIOLOGY

1. *Viability of Excised Appendix.*—In a series of 64 appendixes viability of the muscle tissue was tested immediately and at intervals after operative removal. The specimens were placed in saline solution at room temperature and then were stimulated at intervals by means

43. Warwick, M.: Relationship Between Oxyuriasis and Appendicitis, Am. J. Clin. Path. **5**:238-248, 1935.

of a faradic current. Fifty acutely inflamed appendixes were so treated, and it was noted that the very acutely inflamed and gangrenous specimens gave no muscular response to stimulation even when tested within five minutes after removal. The organs with a mildly acute condition responded up to two hours after removal, and the average duration of response for the entire group of acutely diseased appendixes was 26.3 minutes. In contrast to this, for 14 normal appendixes similarly treated the shortest period of response was two hours and the longest was six and one-half hours. The average length of response for the normal group was three and one-half hours, or eight times as long as for the acutely diseased group. These results appear to indicate that acute inflammation seriously impairs the contractile power of the musculature of the appendix and that this power is entirely lost if gangrene supervenes. The consequent tissue changes which must accompany resolution of the inflammatory process account for the definite organic residual signs of appendicitis.

It was noted that appendixes when stimulated tended always to bend toward the antimesenteric side, indicating that the musculature of the mesenteric side is not as well developed as that on the antimesenteric side. The entering blood vessels account for part of this muscular weakness. After this contraction of longitudinal muscle there was contraction of the circular muscle, the organ becoming smaller in diameter and tending to empty its lumen. These contractions were very slow and lasted for several minutes. The most active motion was observed near the base, and the least activity was near the tip.

2. *Mechanism of Obstruction.*—The effectiveness of obstruction of the appendical lumen by an impacted fecalith was tested in 2 cases, as follows: The specimens were gangrenous appendixes removed at operation; in each a fecalith was impacted in the region of the base. These specimens were gangrenous and showed distention distal to the obstruction, but were normal in caliber and gross appearance proximally. In each instance a fine needle was introduced into the tip of the appendix, and fluid was injected into the distal portion of the lumen. This caused increasing distention of the lumen, but there was no leakage around the fecalith and no fluid escaped from the unclamped base. A cannula then was tied into the base, and fluid readily ran into the appendix, passed the fecalith and distended the distal portion of the lumen. Solution of potassium iodide was used in the lumen, and roentgenograms were taken to show the obstruction (fig. 2). These experiments demonstrated that an impacted fecalith in the appendix serves as an effective ball valve, allowing ingress of fluid but preventing its escape. This makes it easy to see why enemas or diarrhea subsequent to catharsis may hasten perforation of the obstructed appendix.

3. *Theories of Function.*—The appendix is generally considered to be a vestigial structure, without definite function. Boggian and Stellatelli,[44] however, suggested the novel theory that the appendix originates peristalsis which controls the excretory function of the large bowel; that is, when the column of fecal matter in the ascending colon reaches a sufficient weight the appendix is stimulated to contract, and this peristalsis passes the length of the large bowel, causing a desire to defecate. Proponents of this opinion have decried appendectomy as a cause of constipation. Boggian [45] found that the appendical mucosa

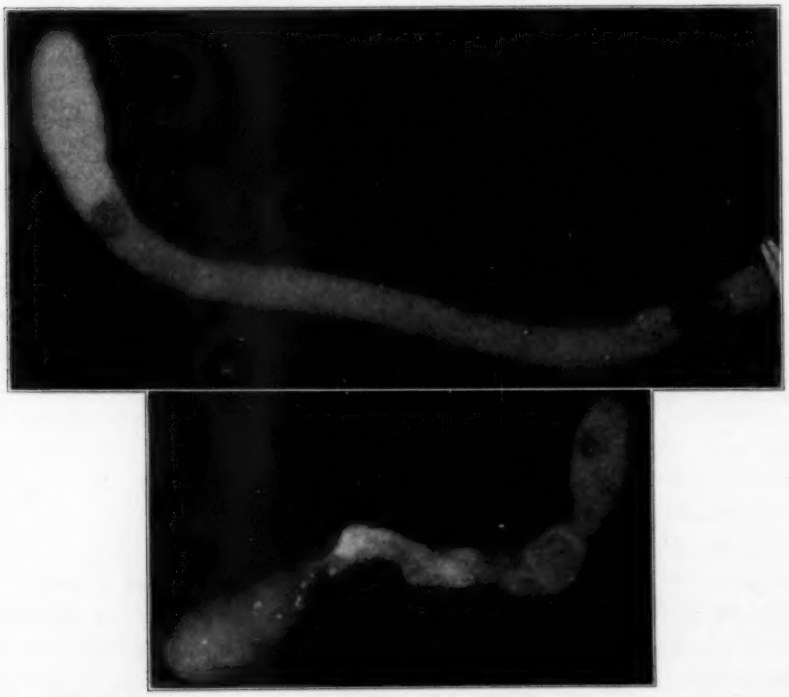

Fig. 2.—Roentgenograms showing obstructing fecaliths in the lumens of acutely inflamed appendixes. Injections of sodium iodide were made into the lumens. In one specimen the lumen is incompletely filled. Lamination and calcification in the fecaliths are shown.

contains a water-soluble substance which stimulates gastric secretion when given by mouth. The significance of this observation is not apparent. Other concepts, mentioned by Kelly and Hurdon,[8] are that

44. Boggian, B., and Stellatelli, M.: Su di una probabile azione fisiologica dell'appendice, Gior. ven. di sc. med. **8**:1145-1151, 1934.

45. Boggian, B.: L'influenza degli estratti di mucosa appendiculare sulla secrezione gastrica, Riforma med. **51**:446-451, 1935.

the appendix secretes a special digestive enzyme specific for cellulose, that it serves to dilute the cecal content, that it secretes a lactopeptone, that it pours out a pancreatic-like juice and that it secretes a hormone. Some authors have reported dire effects on the endocrine glands subsequent to appendectomy.

The most useful observation to date on the physiologic activity of the appendix is that of Wangensteen, Buirge, Dennis and Ritchie.[27] They found that the human appendix, although part of an absorbing segment of bowel, actually secretes fluid at the rate of about 1 to 2 cc. daily and is capable of spontaneously building up an intraluminal pressure of about 40 cm. of water. This is the simplest explanation for the gradual distention and rupture of closed loops of appendix, but there are three other sources of fluid. 1. I[14] have shown that hypertonic contents in the obstructed lumen attract fluid, owing to osmotic imbalance, even in the obstructed cecal appendage of the dog, which normally is an absorbing organ. Under these conditions the volume of fluid in the lumen may increase as much as six times in twenty-four hours. 2. Previously described experiments have shown that an impacted fecalith may allow ingress of fluid from the cecum but prevent its exit, the obstructing fecalith acting as a ball valve. 3. Wilkie[19] has shown that bacterial decomposition of the contents of the lumen produces both fluid and gas, which distend the lumen. Protein content gives the most rapid distention, with early perforation. No doubt a combination of these factors acts to cause perforation in acute obstructive appendicitis.

PATHOGENESIS

1. *Experimental Appendicitis.*—The literature on the experimental pathogenesis of acute appendicitis falls into one of two categories: that which deals with direct experimentation on the appendix or that relating to the physiologic and pathologic character of closed loops of intestine.

(*a*) Direct Experimentation: The older investigators were concerned mainly with attempting to show that organisms from the nasopharynx when injected into the blood stream would localize in the appendix of the experimental animal. Tedesco,[46] Kretz[47] and Adrian[35] injected various organisms into the tonsillar fossae of rabbits and then attempted to show appendical localization. They mentioned, but conveniently avoided considering, that these rabbits showed generalized lymph-

46. Tedesco, F.: Experimenteller Beitrag zur Infektion der Appendix vom Rachenringaus, Arb. a. d. Geb. d. path. Anat. Inst. zu Tübingen **6**:111-119, 1907.

47. Kretz, R.: Untersuchungen über die Aetiologie der Appendicitis, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **17**:1-9, 1907.

adenopathy, septicemia and pneumonia. This indicates that the reaction of the appendical lymphoid tissue was only a part of the general picture of reaction to massive infection. The same criticism applies to the work of Poynton and Paine [48] and to that of Dorsey,[49] who injected streptococci intravenously into rabbits and demonstrated arthritis and appendicitis. Goeters,[50] in a series of rabbits, induced staphylococcic and streptococcic septicemia and then demonstrated the organisms in the lymph spaces of the appendix. Stoeber and Dahl [51] employed similar methods and concluded that in septicemia organisms are excreted into the gastrointestinal tract. Richet and Saint-Girons [52] obtained similar results and concluded that this constant passage of organisms through the tissues of the appendix renders it more liable to infection by organisms in the lumen.

To McMeans [53] goes the credit for demonstrating the fallacies in most of this work. He was able to duplicate the results in most of these experiments with bacterial injection, but obtained similar results after intravenous injection of sterile water into the rabbit. He concluded that the rabbit appendix is essentially a lymphoid organ, not comparable to the appendix of man. He also concluded that no organism is specific for appendicitis and that there is no evidence for appendical localization of organisms from the blood stream.

The work of Heile [54] is significant because he began to use dogs as experimental animals and because he first considered the importance of obstruction in the genesis of inflammation. He observed that the empty obstructed appendix showed no changes, whereas with fecal

48. Poynton, F. J., and Paine, A.: Experimental Appendicitis by General Blood Infection, Tr. M. Soc. London **35**:243, 1912; A Further Contribution to the Study of the Etiology of Appendicitis as a Result of a Blood Infection, with Particular Reference to the Tonsils as a Primary Seat of Infection, Lancet **2**: 439, 1912.

49. Dorsey, A. H. E.: Bacteriology and Pathogenesis of Appendicitis, Surg., Gynec. & Obst. **50**:562-571, 1930.

50. Goeters, W.: Die Beteiligung des Wurmfortsatzes bei Allgemeininfektionen, Virchows Arch. f. path. Anat. **291**:836-911, 1933.

51. Stoeber, H., and Dahl, W.: Experimentelle hämatogene Infektion der Lymphfollikel des Appendix, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **24**:645-651, 1911.

52. Richet, C., and Saint-Girons, F.: Contribution expérimentale à la pathogénie des appendicites hématogènes, Presse méd. **19**:271-272, 1911.

53. McMeans, J. W.: Experimental Appendicitis, Arch. Int. Med. **19**:709-749 (May) 1917.

54. Heile, B.: Ueber Entzündungen des Blinddarmhanges, Verhandl. d. deutsch. Gesellsch. f. Chir. **39**:133-138, 1910; Ueber die Entstehung der Entzündungen am Blinddarmanhang auf bakteriologischer und experimenteller Grundlage, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **26**:345-378, 1913; Die Ursache der akuten Appendicitis im Experiment, München. med. Wchnschr. **72**:211, 1925.

material in the obstructed lumen gangrene, perforation and peritonitis resulted. Boit and Heyde [55] obtained similar results and concluded that obstruction of the lumen resulted in increased virulence of the fecal organisms. Beaussenat and Dieulafoy both found that obstruction of the appendical lumen resulted in gangrene and perforation. Eichoff and Pfannenstiel [56] found that obstruction caused gangrene, but it is significant that they were so influenced by the dictums of Aschoff [57] that they ascribed any inflammatory change to increased virulence of bacteria in the lumen due to stasis. Another criticism of this work is that the animals were allowed to die of perforation and peritonitis or the process to progress to healing. In none of this work were appendixes removed at various intervals and subjected to microscopic examination.

Apparently, Van Zwalenburg [58] had the clearest insight into the problem, but his excellent papers have remained relatively obscure. He stated that simple infection does not account for the suddenness of the attack or for the early severity of the tissue changes in acute appendicitis. He stated that the evident interference with blood supply is best accounted for on the basis of obstruction and increased intraluminal pressure. He recognized that the blood supply to a sterile organ can be cut off with relative impunity for hours, whereas in the appendix serious difficulties arise because of the invasion of the dead tissue by bacteria from the lumen.

Wangensteen and I [16] studied the effects of complete and incomplete obstruction, maintenance of increased intraluminal pressure, isolation of the appendix as a closed loop, the role of various bacteria, interference with circulation and a number of miscellaneous factors in an attempt to determine what factors favor the development of acute appendical inflammation experimentally. We concluded that obstruction and infection are the two most important factors and that the sequence of events is like that in obstruction of a closed loop. We observed

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55. Boit, H.: Ueber experimentelle Appendicitis, Berl. klin. Wchnschr. **49**: 812, 1912. Boit, H., and Heyde, M.: Untersuchungen Experimentelles über die Aetiologie des Appendicitis, Beitr. z. klin. Chir. **79**:271-285, 1912.

56. Eichoff, E., and Pfannenstiel, W.: Untersuchungen über experimentelles Appendicitis, Beitr. z. klin. Chir. **151**:171-202, 1930.

57. Aschoff, L.: Die Wurmfortsatzentzündung: Eine pathologisch-histologische und pathogenetische Studie, Jena, Gustav Fischer, 1908.

58. Van Zwalenburg, C.: (*a*) Obstruction and Consequent Distention the Cause of Appendicitis, as Proved by Cases and by Experimental Appendicitis in Dogs, J. A. M. A. **42**:820-827 (March 26) 1904; (*b*) The Relation of Mechanical Distention to the Etiology of Appendicitis, Ann. Surg. **41**:437-450, 1905; (*c*) Strangulation Resulting from Distention of Hollow Viscera, ibid. **46**:780-786, 1907; (*d*) Hydraulic Vicious Cycle in the Intestine, Am. J. Surg. **18**:104-112, 1932.

that the obstructed cecal apex of the dog always became inflamed unless the lumen was washed clean, and then there were no changes even after six weeks. We also found that constant intraluminal pressures up to 15 cm. of water acting for six to eighteen hours produced changes in the tissues ranging from acute to gangrenous.

Recently, Wangensteen, Buirge, Dennis and Ritchie [27] have shown that if a needle is introduced into the tip of the human appendix there is resistance to the free flow of water into the cecum. Investigations on 96 specimens showed the following degrees of water pressure to be sustained:

	Average, Cm.	Maximum, Cm.	Minimum, Cm.
Normal appendixes	38	110	16
Appendixes removed after interval	54	130	16
Acutely inflamed appendixes	73	120	12
Appendix of cadavers	3	9	0

These results indicate that even in the absence of definite organic obstruction to the lumen a considerable degree of pressure can be built up in the appendix. The same authors have shown that the appendix of man and that of the rabbit secrete fluid and so tend to distend as a closed loop. They found that the usual volume of the lumen of the appendix in man ranges between 0 and 0.3 cc. In a series of specimens the volume of the lumen at which rupture occurred was determined. The average volume was 5.8 cc., the maximum was 9 cc. and the minimum was 3 cc. Gangrenous appendixes were found to rupture at a pressure of 70 cm. of water, and normal appendixes at a pressure of 1,500 cm. of water. They also found that if the vessels in the mesentery of an obstructed rabbit appendix were ligated no secretion into the loop occurred. Otherwise, rupture occurred in about three hours, pressures up to 72 cm. of water having been built up spontaneously. Rupture could be much hastened by oral administration of croton oil or intravenous injection of hypertonic solution of sodium chloride.

(*b*) Indirect Evidence: The results of the foregoing investigations have led to the conclusion that the appendix may act as a closed loop. They make pertinent, therefore, a consideration of the literature bearing on this point.

Gatch [59] and Dragstedt and their associates [60] have shown that distention of the bowel reduces its blood supply and that if pressure

59. Gatch, W. D.; Trusler, H. M., and Ayers, K. D.: Effects of Gaseous Distention on Obstructed Bowel: Incarceration of the Intestine by Gas Traps, Arch. Surg. **14**:1215-1221 (June) 1927.

60. Dragstedt, C. A.; Lang, V. P., and Millet, R. F.: Relative Effects of Distention on Different Portions of Intestine, Arch. Surg. **18**:2257-2263 (June) 1929.

is such as to shut off the arterioles gangrene results. Van Beuren [61] gave this as the mechanism of perforation in intestinal obstruction. Sperling [62] and Herrin and Meek [63] found that obstruction is an intense secretory stimulus, and Burget and his associates [64] observed that dogs with closed loops of jejunum could be kept alive only by repeated aspiration of the contents of the loop to prevent distention, gangrene and perforation. Van Zwalenburg [58d] stated that distention increases peristalsis and secretion, which augment distention, and thus a hydraulic vicious cycle is established.

Parker,[65] Banks [66] and others have shown that carcinoma of the cecum may occlude the appendical orifice and thus form a closed loop in which acute inflammatory changes develop. Rost,[67] Sperling [68] and others have demonstrated that obstructing carcinoma of the sigmoid flexure of the colon may cause perforation of the cecum in the presence of a competent ileocecal sphincter, owing to distention of this closed loop. These observations when applied to the appendix make it easy to understand the changes incident to the development of a closed loop. It has been shown in a previous paper [14] that acute and gangrenous changes may develop even in sterile organs in which increased intraluminal pressure is maintained (fig. 3).

2. *Clinical Pathogenesis.*—It is recognized that foreign bodies may erode the appendical wall, that infection may develop in other ways or that trauma may cause appendicitis, but the following sequence of events is postulated as that which usually operates in the development of acute appendicitis.[58b]

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61. Van Beuren, F. T.: Mechanism of Intestinal Perforation Due to Distention, Ann. Surg. **83**:69-78, 1926.

62. Sperling L.: Mechanics of Simple Intestinal Obstruction: An Experimental Study, Arch. Surg. **36**:778-815 (May) 1938.

63. Herrin, R. C., and Meek, W. J.: Studies in Intestinal Obstruction, Am. J. Physiol. **97**:532-533, 1931.

64. Burget, G. E.; Martzloff, K.; Suckow, G., and Thornton, R. C. B.: Closed Intestinal Loop: Relation of the Intraloop (Jejunum) Pressure to the Clinical Condition of the Animal, Arch. Surg. **21**:829-837 (Nov.) 1930. Burget, G. E.; Martzloff, K. H.; Thornton, R. C. B., and Suckow, G. R.: Closed Intestinal Loop: Observations on Dogs with Jejunal and Ileal Loops and Chemical Analyses of Blood, Arch. Int. Med. **47**:593-600 (April) 1931.

65. Parker, G. E., and Rosenthal, D. B.: Carcinoma of the Large Bowel as the Direct Cause of Acute Appendicitis and Simultaneous Acute Intestinal Obstruction, Lancet **2**:1089-1090, 1933.

66. Banks, A. G., and Green, R. D.: Acute Appendicitis Associated with Carcinoma of the Caecum, Brit. M. J. **1**:926, 1935.

67. Rost, F.: Pathological Physiology of Surgical Diseases, Philadelphia, P. Blakiston's Son & Co., 1923, p. 222.

68. Sperling, L.: Role of the Ileocecal Sphincter in Cases of Obstruction of the Large Bowel, Arch. Surg. **32**:22-48 (Jan.) 1936.

(*a*) Probable Sequence of Events: The lumen of the appendix becomes occluded by a slowly enlarging fecalith or by some other mechanism, and a closed loop is thus formed. Peristalsis is stimulated as the appendix attempts to overcome the obstruction, and the patient notices cramplike pains in the abdomen. The peristalsis, together with the obstruction, acts as a secretory stimulus, and the lumen gradually fills with fluid from this source and also from the action of bacteria on its contents. The distention causes pressure on the terminations of the sympathetic nerves, and the patient experiences pain, of a more

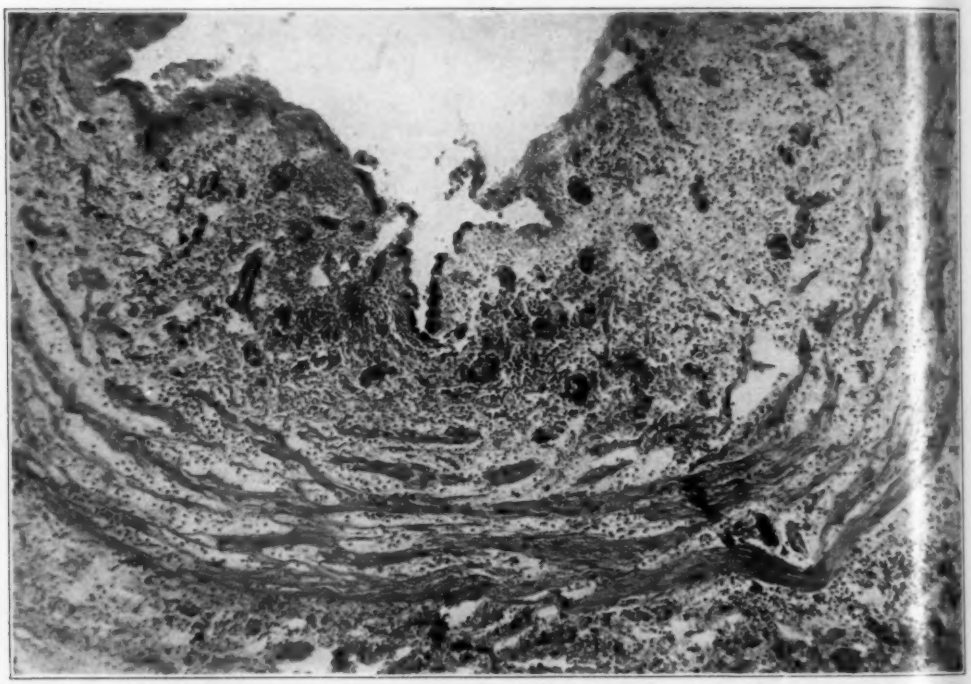

Fig. 3.—Sterile ureter of a dog. Gangrenous changes were induced in this ureter by maintenance of a constant intraluminal pressure of 15 cm. of water for eighteen hours. The kidney also showed acute inflammatory changes as a result of the pressure within the sterile renal pelvis. Note that this microscopic picture closely resembles that seen in severe appendicitis, with mucosal ulceration, dense infiltration with leukocytes and separation of muscle bundles by accumulation of inflammatory exudate.

constant nature and usually referred to the umbilical region.[69] As distention increases, the capillaries and venules become occluded, while in the arterioles blood continues to be pumped in at systolic pressure.

69. Friedrichs, A. V.: Etiology and Pathology of Appendicitis, New Orleans M. & S. J. **87**:20-24, 1934.

Vascular congestion follows, and edema and diapedesis of leukocytes begin. The distention has now reached such proportions that reflex nausea and vomiting occur, and the patient has such severe pain that it is recognized as coming from the right lower quadrant of the abdomen. Distention progresses, and inflammatory reaction increases until the terminations of the visceral afferent nerves are killed by pressure or by anoxemia. The pain then becomes less. The distention now has completely shut off the capillaries and smaller veins, so that thrombosis occurs. The antimesenteric border has the poorest blood supply; here diamond-shaped infarcts develop first. The reaction has now reached the serosa, so that the patient experiences pain from a peritoneal source and rebound tenderness with rigidity can be elicited. As more blood is pumped into the appendix the smaller vessels rupture, and hemorrhage occurs. By this time the walls distal to the obstruction are thinned by distention, and the mucosa has become ulcerated and destroyed as a result of pressure necrosis. Fever, rapid pulse and leukocytosis have developed as a consequence of absorption of dead tissue products. As soon as necrosis of tissue appears bacteria may enter the tissues. If the appendix is not able to overcome the obstructing mechanism [58c] perforation eventuates, usually through one of the infarcted areas on the antimesenteric border. At this stage the patient experiences relief of pain, due to release of pressure. Westphal [22] suggested that anaerobes form gas in the lumen and that perforation is in the nature of an explosion.

(*b*) Cause of Regression: The appendicitis may regress spontaneously if the appendix can expel the fecalith, overcome any other type of obstruction which may be present or dissolve the fecalith. Ochsner [70] stated that he had several times found the fecalith just escaping into the cecum, owing to relaxation caused by the anesthetic. He also had found fecaliths in the cecum, evidently just expelled. Ochsner also saw appendixes distended by gas and obstructed at the base by spasm. In this series it frequently has been noticed that with long duration of the disease the fecalith becomes soft and tends to disintegrate. Some were recognized by the marked depression left in the mucosa at the site of obstruction, and others were identified by concentrically placed masses of calcareous material on roentgen examination. The possibility of neurogenic spasm or anomaly of the sphincter at the appendical base has not been considered in this investigation.

(*c*) Effect of Catharsis on Perforation: Catharsis long has been known to favor perforation in appendicitis. Schmidt [71] showed a

70. Ochsner, A. J.: A Handbook of Appendicitis, Chicago, G. P. Engelhard & Co., 1902.

71. Schmidt, cited by Egdahl.[20]

postcathartic mortality of 8.6 per cent as compared with a total mortality of 5 and 1.2 per cent for primary appendicitis without rupture. It may be that one bad effect of the cathartic is simply that the patient delays consulting a physician until the cathartic has had an opportunity to act, but it seems more likely, from experimental evidence, that the cathartic stimulates peristalsis and secretion, thus hastening perforation of the obstructed appendix. Enemas also may cause perforation by overdistention of the appendix. In this connection it should be stated that the various diagnostic tests which depend on back pressure into the appendix to cause pain should be avoided because of the possibility of traumatic perforation of the viscus (fig. 4).

(*d*) Experimental Recapitulation: In order to test the foregoing theory of pathogenesis, 3 patients in the "interval" group were operated

Fig. 4.—Changes in the appendical wall and lumen incident to obstruction. The position of the obstructing fecalith is shown, and it will be noted that distal to this point the lumen is dilated, the mucosa is sloughing, the wall is very thin and the mesenteric vessels are thrombosed. Proximal to the obstruction the lumen is of normal caliber and the wall is of ordinary thickness.

on with the region under local anesthesia. The cecum was delivered onto the abdominal wall, and the base of the appendix was ligated. This procedure caused the patient no pain. A fine needle was then introduced into the appendical lumen through the tip, and saline solution was introduced gradually through a syringe. In 1 patient moderate distention caused marked blanching of the organ, and with progressive distention the decrease in circulation could be visualized. This patient had severe generalized abdominal pain, which was abolished by cutting the mesoappendix. Some fluid was transuded through the appendical wall; this may indicate in part the formation of peritoneal fluid. In a second patient a similar procedure was carried out, and it was found that an acute pressure of 125 cm. of water in the appendix did not

cause pain because the musculature contracted violently and there was no distention. When the syringe was used and saline solution was injected slowly over a period of minutes, 6 cc. caused emptying of the vessels along the antimesenteric border; the walls became thinned, owing to distention, and fluid was exuded. The patient had generalized abdominal pain, and with increased distention this pain localized in the right lower quadrant. After the saline solution was aspirated from the lumen the appendix contracted and became hyperemic, but remained 1.5 cm. longer than before distention. The lumen was distended again, and the pain was relieved by cutting the mesoappendix. In the third patient, similarly prepared, slow distention caused vague abdominal discomfort, followed by pain in the right lower quadrant and nausea. These symptoms were relieved by aspirating the solution or cutting the mesoappendix. The patient said that this procedure caused symptoms closely simulating those of previous spontaneous attacks which had been diagnosed as acute appendicitis.

BACTERIOLOGY

According to the obstructive theory of the origin of appendicitis, bacteria are purely secondary to mechanical factors in the majority of cases. Nevertheless, it was felt advisable to conduct investigations with regard to the flora of the appendixes in this series.

1. *Postmortem Changes.*—In reviewing the literature it was found that some authors stated that appendixes removed at emergency operation during the night were placed in the ice box until morning, when material was taken for culture. It was my thought that postmortem invasion might account for many of the cultures yielding bacteria in such cases; the following experiment, therefore, was carried out. In 8 cases the operatively excised appendix was placed in saline solution at room temperature. A cross section of the organ was taken at the tip and placed in solution of formaldehyde. These appendixes were allowed to remain in the saline solution, and contiguous sections were removed and fixed after intervals ranging from five to twenty-four hours. Results in sections prepared with the Gram stain (table 3) are shown in the table.

The postmortem bacterial invaders tended to occur in rather large clumps and were not surrounded by any tissue reaction. The foregoing experiment shows the necessity of taking material for culture immediately after excision of the appendix.

2. *Clinical Bacterial Studies.*—From 30 appendixes (10 from patients with interval appendectomies, 10 from patients with acute appendicitis and 10 from patients with gangrene of the appendix) cultures of peritoneal fluid, of the contents of the distal and proximal

portions of the lumen and of a segment of serosa and muscularis from the distal portion were taken at the operating table. This material was incubated in liver-peptone broth, and if it was sterile after seventy-two hours no further investigation was carried out. After twenty-four hours smears of the cultures were made and stained by the Gram method. If gram-positive rods were found, milk tubes were inoculated and read for proteolytic and gas-forming organisms. The liver-peptone cultures were planted on eosin-methylene blue and blood agar plates. After twenty-four hours these plates were read for streptococci and colon organisms, and the latter were differentiated according to fermentation reactions.

TABLE 3.—*Correlation* Between the Number of Bacterial Colonies in the Tissues and the Length of Time Elapsing Between Excision of the Appendix and Preparation of the Material for Bacteriologic Study*

Case No.	Fixation of First Section	Result	Time of Fixation of Second Section After Removal	Result
1	On removal	Few colonies in submucosa	5 hr. later	No definite increase in colonies
2	On removal	No bacteria in tissues	16 hr. later	Many colonies in all tissue layers
3	On removal	No bacteria in tissues	16 hr. later	Many colonies in all tissue layers
4	On removal	No bacteria in tissues	24 hr. later	Extremely numerous bacterial colonies
5	On removal	Few clumps of bacteria	24 hr. later	Apparently fewer than in early fixation
6	On removal	No bacteria in tissues	24 hr. later	Many colonies in all layers
7	1 hr. after removal	No bacteria in tissues	24 hr. later	Many colonies in all layers
8	1 hr. after removal	Few colonies in submucosa	24 hr. later	Dense infiltrating clumps of bacteria

* This relation is proof that in order to eliminate error one should prepare the material for study immediately after removal of the appendix.

In these 30 cases a direct correlation was found between the severity of the disease and the presence of bacteria in the tissues. The culture method revealed bacteria in the following percentage of cases:

	Appendectomy After Interval	Acute Appendicitis	Gangrene
Tissue	0	20%	60%
Peritoneum	20%	10%	0
Lumen	90%	100%	100%

The 20 per cent incidence of bacteria in the peritoneal cavity in the cases of interval appendectomies is due to the fact that in these cases there was a residual abscess from the previous perforation. In the same group one lumen was sterile, but this was a mucocele.

Comparison of Tissue Gram Stain and Culture Methods.—There seems to be a general feeling among pathologists that the method

of demonstrating bacteria by staining tissues with Gram's stain is not reliable. In this series there was an excellent opportunity to evaluate this idea, for the two methods were used simultaneously and were checked against each other. The percentage of cases in which the results were positive are compared for the two methods as follows:

	Acute Appendicitis	Gangrene	Appendectomy After Interval	Gynecologic Group	Experimental Series
Gram tissue stain	21%	63%	2%	21%	19%
Culture method	20%	60%	0		

It is interesting to note that in each group the Gram tissue stain gave a slightly higher percentage of positive results than the culture method.

The various types of organisms and the frequency with which each occurred, as shown by the culture method, were as follows:

	Bacillus Coli Communis	Bacterium Coli Communior	Bacillus Aerogenes	Streptococcus Haemolyticus	Staphylococcus	Proteolytic Anerobe	Clostridium Welchii
Tissue	17%	7%	3%	3%	7%	7%	0
Peritoneum	7%	0	0	3%	0	0	0
Distal part of lumen	7%	3%	3%	0	0	7%	3%
Proximal part of lumen	27%	27%	20%	3%	0	13%	3%

The gram-positive diplococci described by Aschoff and also by Gundel and his associates [72] were not observed in this investigation. This is the usual experience of American authors. The incidence of mixed organisms in this series, as shown by the culture method, was as follows:

	1 Organism	2 Organisms	3 Organisms
Tissue	10%	17%	0
Peritoneum	3%	3%	0
Distal part of lumen	0	0%	3%
Proximal part of lumen	30%	23%	6%

It is interesting to note that the lumens of normal appendixes appeared to contain more organisms than did those of inflamed appendixes. This observation has been made by other investigators, but no especial significance can be attached to it, as it may be simply a phenomenon of dilution.

In 17 per cent of cases of acute appendicitis due to obstruction, bacteria were present in the tissues, as compared with 9 per cent in the group in which no obstruction was present. This agrees with the results in the experimental series [15] and probably means that increased intraluminal pressure in the presence of obstruction forces bacteria into the tissues.

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72. Gundel, M.: Ueber die "Erregerfrage" bei der Appendicitis und postappendicularen Peritonitis, Arch. f. klin. Chir. **172**:597-623, 1933. Gundel, M.; Paget, W., and Sussbrich, F.: Untersuchungen zur Aetiologie der Appendicitis und postappendicularen Peritonitis, Beitr. z. path. Anat. u. z. allg. Path. **91**:399-438, 1933.

4. *Bacteria in Appendical Peritonitis.*—In the Minneapolis General Hospital series, 11 cases of appendicitis with perforation and peritonitis were studied with reference to the bacterial content of the peritoneal exudate. Bacteria were found in the peritoneum in 81 per cent of cases. In 36 per cent of cases there was only one type of organism; in 27 per cent there were two types; in 9 per cent there were three types, and in 9 per cent there were four types. The following organisms were isolated. The incidence of each was as follows:

	Incidence, %
B. coli communis	45
Bact. coli communior	45
Enterococcus	27
Str. haemolyticus	18
Bacillus fusiformis	9
Diphtheroids	9

Twelve cases of nonperforative appendicitis in the same series were similarly studied; in only 16 per cent were there bacteria in the peritoneal cavity. Bact. coli communior was isolated in 1 case and Streptococcus viridans in another.

5. *Review of Literature.*—In the general enthusiasm over the theory of the bacterial causation of disease, mechanical factors were forced into the background, where they have remained to this day, largely owing to the writings of Aschoff and others, who postulated a specific bacterial cause for appendicitis and all other diseases. Rosenow,[73] in 1915, obtained cultures yielding bacteria from the walls of 17 of 18 acutely diseased appendixes. The organisms usually were B. coli and Str. viridans. These organisms when injected intravenously into rabbits were said to have resulted in acute appendicitis. The previously cited work of McMeans [53] threw doubt on these results, however. In 1921, Rosenow [74] went so far as to state that organisms isolated in cases of peptic ulcer, cholecystitis, appendicitis and pancreatitis produced similar lesions when injected intravenously into experimental animals. His enthusiasm for the theory of elective localization of bacteria has not been generally shared.

In 1925, Warren [75] studied a series of acutely diseased appendixes by gram-stained sections and by cultures of the serosa and muscularis. He observed all early lesions to be located at the margins of the lumen, an observation which he interpreted as evidence against the hematogenous route of infection. Warren was not able to demonstrate the organism described by Aschoff, and he concluded that appendicitis is

73. Rosenow, E. C.: Bacteriology of Acute Appendicitis, J. Infect. Dis. **16**: 240-268, 1915.

74. Rosenow, E. C.: Focal Infection and Elective Localization of Bacteria, Surg., Gynec. & Obst. **33**:19-26, 1921.

75. Warren, S.: Etiology of Acute Appendicitis, Am. J. Path. **1**:241-246, 1925.

not a specific bacterial disease. In a series of 288 cases he found B. coli alone in 57 per cent, B. coli and streptococci in 19 per cent and streptococci alone in 8 per cent.

The idea that organisms swallowed from the throat may set up appendical inflammation has intrigued many investigators. Hilgermann and Pohl [76] presented the following figures in this regard:

	Single Organism			Combined with Other Organisms	
Organism	Throat and Appendix	Throat	Appendix	Appendix	Throat
Pneumococcus	56%	19%	4%	60%	75%
Streptococcus	27%	35%	5%	32%	64%
Diphtheroid	7%	1%	3%	10%	8%
Staphylococcus	13%	19%	0	14%	32%
Vincent's bacillus	9%	1%	0	11%	10%

Gundel [72] stated that he had isolated the same strain of pneumococci from the throat and from the appendix in a series of cases, and he postulated primary pneumococcic infection with secondary invasion by putrefactive and colon bacilli. All blood cultures were sterile. Gundel found that most inflamed appendixes did not show intestinal flora. In 27 of 31 cases he isolated a gram-positive diplococcus, and in 10 of 15 cases the same organism was seen in microscopic sections. He found the same organism to be the one most frequently phagocytosed and most frequently isolated from the pus of appendical abscesses. From these observations Gundel concluded that a gram-positive diplococcus is the most frequent cause of appendicitis. The usual fecal type of flora could be isolated in cases of so-called chronic appendicitis.

Meleney, Harvey and Jern,[77] in an excellent paper, reported that the incidence of anaerobes was less than 50 per cent in cases of perforative appendicitis and that these organisms were scarce in cases of gangrene of the appendix. They concluded that gangrene is vascular rather than bacterial in origin. In no case did death occur in the absence of perforation, even though several organisms could be cultured from the peritoneal fluid.

Cazzamali and Miglierina [78] concluded that the peritoneal fluid in cases of early appendical peritonitis is apt to be sterile but in the late stage of the disease is polymicrobic. They found that anaerobes traverse the appendical wall with difficulty in the absence of perforation.

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76. Hilgermann, R., and Pohl, W.: Beitrag zur Aetiologie und Serumtherapie der foudroyanter Appendicitis auf Grund der Beobachtungen bei 300 Fällen im Kreise Deutsch-Krone, Arch. f. klin. Chir. **154**:248-319, 1929.

77. Meleney, F. L.; Harvey, H. D., and Jern, H. Z.: Peritonitis: Correlation of the Bacteriology of the Peritoneal Exudate and the Clinical Course of the Disease in One Hundred and Six Cases of Peritonitis, Arch. Surg. **22**:1-66 (Jan.) 1931.

78. Cazzamali, P., and Miglierina, R.: La batteriologia delle peritoniti acute, Arch. ital. di chir. **34**:573-675, 1933.

Recently, Collins [79] has investigated the bacteriologic features of chronic appendicitis. In a total series of 209 cases he obtained tissue cultures yielding bacteria in 16.2 per cent. All of the totally obliterated appendixes were sterile, but 47 per cent of the cultures yielding bacteria were of tissue from partially obliterated appendixes.

The results of this investigation and those of the work of most other authors indicate that appendicitis is not specifically a bacterial disease. The results of this investigation seem to indicate that bacteria appear late or not at all in the course of appendicitis and therefore play a secondary role in the causation.

PATHOLOGY

1. *Mortality.*—Tasche and Spano [29] reported a mortality rate (1922 to 1930) of 3.4 per cent for a series of 700 cases, while Sperling and Myrick [80] reported a rate of 5.6 per cent for 518 cases observed subsequently (1932 to 1935) at the same hospital. The mortality rate in this series is shown in table 4. There was a total mortality of 1.08 per cent for the entire series.

TABLE 4.—*Mortality Rate in the Present Series* *

	Cases		Deaths		Mortality, Percentage	
	Minneapolis General Hospital	University Hospitals	Minneapolis General Hospital	University Hospitals	Minneapolis General Hospital	University Hospitals
Interval appendectomy	16	131	0	0	0	0
Acute appendicitis	49	43	0	0	0	0
Gangrene	20	57	0	0	0	0
Perforation and local peritonitis	12	4	2	0	16.66	0
Perforation and general peritonitis	22	0	2	0	9.09	0
Total	119	235	4	0	11.76	0
Nonperforative acute appendicitis	69	100	0	0	0	0
Perforative appendicitis	34	4	4	0	11.76	0

* The Minneapolis General Hospital series includes all appendixes removed at that institution in 1935. The University Hospitals series includes all appendixes removed there in 1936. Cases in which no operation was done have not been included in this study.

2. *Cause of Death.*—Peritonitis is the usual cause of death, but in this series it did not enter into the picture. Of the 4 fatalities, 1 patient died of pulmonary embolism on the eighth postoperative day. Another died of cerebral hemorrhage and pneumonia on the thirtieth postoperative day. The third died of mastoiditis, thrombosis of the

79. Collins, D. C.: Bacteriologic Studies of Chronic Appendicitis, Ann. Surg. **103**:870-874, 1936.

80. Sperling, L., and Myrick, J. C.: Acute Appendicitis: Review of Five Hundred and Eighteen Cases in University of Minnesota Hospitals from 1932 to 1935, Surgery **1**:255-264, 1937.

lateral sinus and septicemia more than a month after appendectomy, and the fourth had scarlet fever on the eighth postoperative day, followed by pneumonia, septicemia and death more than a month after appendectomy. In a study of 1,000 cases of fatal peritonitis, Pflaum [81] found appendicitis to rank second as the cause of peritonitis, being responsible in 12.6 per cent of cases.

3. *Obstruction.*—The incidence of definite luminal obstruction in the present series was 80 per cent and the distribution among the groups was as follows:

	Acute Appendicitis	Gangrene	Localized Peritonitis	Generalized Peritonitis	Colic	Appendectomy After Interval	Parasites	Gynecologic Group
Minneapolis General Hospital	75%	90%	100%	95%	100%	37%	0	...
University Hospitals	23%	84%	100%	....	.....	20%	57%	3%
Total	49%	87%	100%	95%	100%	28%	28%	3%

The obstruction was an impacted fecalith in 67 per cent of cases, and other factors operated in the following number of instances (fig. 5).

Obstruction	Acute Appendicitis	Gangrene	Appendectomy After Interval
Anatomic position	1	5	4
Inspissated feces	2	2	5
Polyps	1	1	2

This classification does not include the organic residual signs of previous appendicitis, which will be discussed under another caption (fig. 6).

The patients in the pediatric age group (up to 16 years) were studied as to the presence of obstruction and incidence of fecaliths. It was found that for the pediatric groups the incidence of obstruction was about 5 per cent greater than for the adults and the incidence of fecaliths was about 10 per cent greater than for the adults.

	Acute Appendicitis				Gangrene				Perforative Appendicitis			
	Obstruction		Stone		Obstruction		Stone		Obstruction		Stone	
	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
Pediatric group	9	38	12	46	18	90	14	74	11	100	9	90
Adult group	35	53	22	34	48	83	35	63	25	96	23	82

4. *Increased Intraluminal Pressure.*—The incidence of increased intraluminal pressure as evidenced by distention of the lumen and flattening of the mucosal folds is fairly closely correlated with the presence of obstruction. In most cases incision of the appendical wall caused the contents to be forcibly ejected. That flattening of the mucosa results from intraluminal distention was shown by fixing normal appendixes with their lumens distended by saline solution. These appendixes showed flattening and desquamation of epithelium similar

81. Pflaum, C. C.: A Postmortem Analysis as to Etiology in One Thousand Cases of Peritonitis, Am. J. Clin. Path. **5**:131-150, 1935.

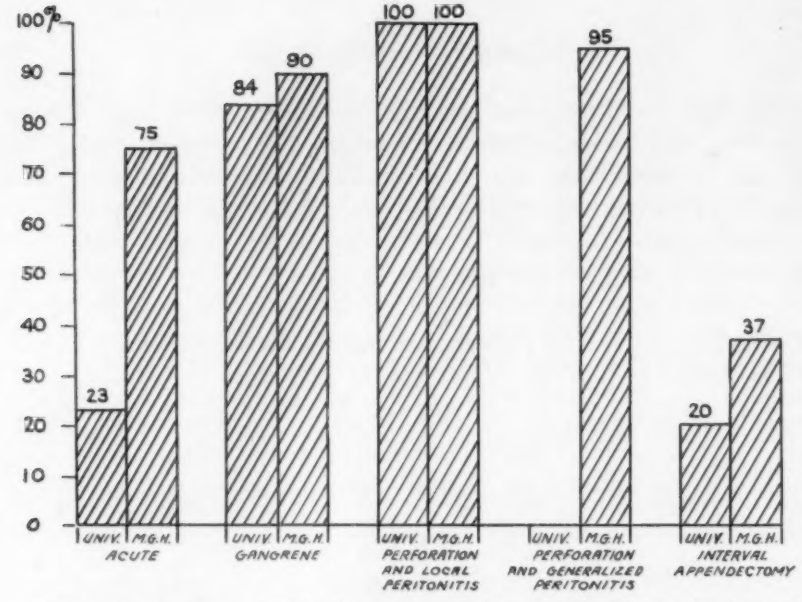

Fig. 5.—Incidence of organic obstruction of the appendical lumen in the various types of appendicitis is this series. In the University Hospitals series no patient with perforation and generalized peritonitis was subjected to primary operation. Such patients were treated conservatively, and the appendix was removed after about six weeks.

Fig. 6.—Polypoid area, containing large amounts of lymphoid tissue. One can see readily how slight edema of this area would completely block the appendical lumen and lead to the formation of a closed loop, with its attending dangers.

to the changes seen in acute appendicitis. The incidence of increased intraluminal pressure in this series was as follows:

	Acute Appendicitis		Gangrene		Localized Peritonitis		Generalized Peritonitis		Colic		Appendectomy After Interval		Gynecologic Group	
Minneapolis	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
General Hospital	32	65	20	100	10	81	12	54	4	80	1	7	..	..
University Hospitals	6	15	36	63	4	100	..	..	..	..	20	15	1	3
Total		40		81		90		54		80		11		3

Release of pressure by perforation is the obvious reason for the smaller incidence of demonstrable pressure in the cases in which perforation and peritonitis were present.

In this series 2 appendixes showed diverticula. These pouches contained fecaliths and evidently had been formed as the appendix attempted to expel the concretion. On section these pouches were seen to contain no muscle fibers in their walls.

Williams and Boggon [82] observed obstruction of the lumen in 97.2 per cent of a consecutive series of 108 acutely diseased appendixes and noted that inflammation was confined to the obstructed area. Diverticula distal to the obstruction were found in 6 cases. Edwards [83] observed 8 cases of diverticula in 1,493 appendixes. The diverticula were multiple in all instances and were seen in cases in which there was stenosis of the lumen at the base of the appendix. Edwards concluded that these pouches develop as a result of increased intraluminal pressure, but he did not suggest that the pressure may cause appendicitis. These pouches were most often seen on the mesenteric side, where the muscle layer is weakened by the vascular hiatuses.

5. *Incidence of Recurrence.*—Such microscopic observations as fibrosis of the submucosal and muscular layers, abnormal, irregular thickening and vascularity of the serosa and foci of lymphocytes or plasma cells throughout the tissues have been taken as evidence of previous acute inflammation. These changes had the following incidence in this series:

	Acute Appendicitis		Gangrene		Localized Peritonitis		Generalized Peritonitis		Appendectomy After Interval		Parasites		Gynecologic Group	
Minneapolis	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
General Hospital	17	36	5	25	0	0	4	18	16	100	1	20	5	17
University Hospitals	11	25	6	10	1	25	..	..	119	91	7	85	13	40
Total		30		17		12		18		95		52		28

82. Williams, B. W., and Boggon, R. H.: Mechanics of Appendicitis, Lancet **1**:9-10, 1934.

83. Edwards, H. C.: Diverticula of the Appendix, Brit. J. Surg. **22**:88-107, 1934.

These figures are much lower than those for cases in which there is a history of previous attacks, but show the same tendency toward more attacks in cases of the less severe grades of appendicitis. It should be mentioned that the figures for the gynecologic group are not particularly significant, since the group was not made up of unselected material. The appendixes usually were removed because of some appearance of gross deviation from the normal.

6. *Chronic Appendicitis and Appendical Colic.*—From the severe changes in the muscle layer in the cases of appendectomy after an interval, as studied by the azocarmine stain, it was concluded that normal function would be impossible, and it was postulated that the repeated mild attacks of pain making up the syndrome usually called chronic appendicitis may have a basis of muscular dysfunction and colic. To test this idea, 4 of the patients in this group were operated on with the region under local anesthesia. In each case the cecum was delivered onto the abdominal wall and the patient was observed to be comfortable. The appendix then was stimulated by means of a faradic current. This resulted in marked contraction and spasm of the appendix, causing severe pain in the right lower quadrant. The appendix became white from the extreme degree of contraction. The patients thought that this simulated the attacks for which they had come to the hospital.

Aschoff [57] stated that 80 per cent of patients show microscopic evidence of previous appendicitis by the fifth decade of life. According to Cutler,[84] Williams and Boggon,[82] Boyd [85] and others, repeated attacks of appendicitis convert the submucosa into dense fibrous tissue (fig. 7). This fibrous tissue also invades the muscularis and breaks up the muscle bundles into isolated strands. The serosa becomes markedly thickened, more vascular and infiltrated with lymphocytes and plasma cells, together with new fibrous tissue. Cutler [84] stated that disturbed function rather than inflammatory change is the most constant evidence of recurrent appendicitis. It seems possible that the residual fibrosis produces enough muscular dysfunction to cause recurrent mild attacks of pain—so-called chronic appendicitis. Cole [86] stated that dysfunctioning or chronically diseased appendixes cause recurring attacks of pain in the right lower quadrant which does not radiate and is not accompanied by signs of acute inflammation. Bigelow [87] operated

84. Cutler, O. I.: Mild Acute Appendicitis: Appendical Obstruction, Arch. Surg. **31**:729-741 (Nov.) 1935.

85. Boyd, W.: Surgical Pathology, Philadelphia, W. B. Saunders Company, 1929, pp. 362-381.

86. Cole, W. H.: Differential Diagnosis and Treatment of Chronic Appendicitis, J. A. M. A. **105**:147 (July 13) 1935.

87. Bigelow, W. A.: Study of Right-Sided Pain in So-Called Chronic Appendicitis, Canad. M. A. J. **23**:22-23, 1930.

on patients with chronic appendicitis with the region under local anesthesia and found that pinching the appendix was followed in two or three minutes by spasm and typical severe cramplike pains. Pulling on the mesoappendix caused localized pain in the region of the appendix. Gargano [88] made an observation which correlates well with these ideas. He examined appendixes by polarized light and found that in chronic appendicitis the musculature does not exhibit double refractility, which is characteristic of normal muscle. This indicates an incomplete return to normal after acute inflammation.

7. *Microscopic Picture.*—A study of the pathologic changes in appendicitis is complicated by the fact that pathologists divide the disease arbitrarily into several types and speak of each as a definite entity. This

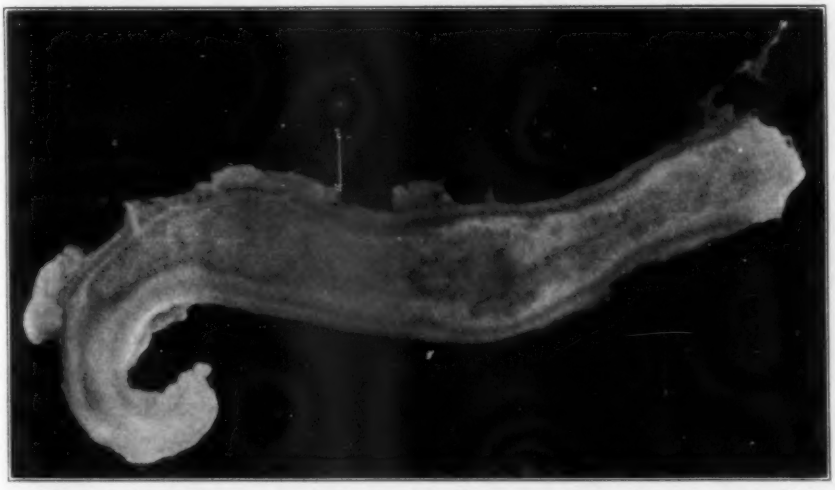

Fig. 7.—Appendix removed six weeks after an attack of acute appendicitis, which was treated conservatively. The gross specimen shows obliteration of the lumen in the distal fifth of the appendix. The area of dilatation contained a small fecalith. The white submucosa in this area was fibrotic on section.

attitude has led to the use of such terms as "catarrhal appendicitis," "suppurative appendicitis" and "gangrene of the appendix" without regard to the fact that the disease is progressive and passes through a gradual series of changes, culminating in gangrene and perforation unless the infection is controlled or the obstruction is overcome. The microscopic picture in any given case of appendicitis simply indicates the point to which the disease has advanced before being arrested by the surgeon.

The lumen on microscopic section gives valuable information not only by its size and conformity but by its content. A diagnosis of

88. Gargano, cited by Kelly and Hurdon.[8]

obstruction can be made from examination of the section under low magnification, for dilatation of the lumen distal to the point of obstruction is invariably present whereas the lumen proximally is normal in caliber. If a fecalith has been the cause of obstruction an area of flattened mucosa is seen at the point of its impaction. The contents of the obstructed appendix are always fluid, as is true of obstructions elsewhere in the intestinal tract. The contents are made up of cellular exudate, bacteria and liquefied feces containing masses of cellulose, and in the presence of obstruction due to a fecalith there are flecks of calcareous material in the liquid content of the distal portion. In cases in which the condition is not due to obstruction the lumen is uniform in diameter, there being no dilatation in the absence of obstruction. The contents tend to be more purulent, and the fecal material, if present, may be solid. In appendixes removed after an interval of treatment the lumen is apt to contain inspissated masses of fecal matter, owing to the muscular dysfunction. Strictures and minor irregularities of the lumen are common as a result of patchy fibrosis in healing.

The mucosa has been studied incompletely by investigators, so that the normal histologic picture is not a matter of agreement among pathologists. For this reason there is much confusion arising from its examination in cases of appendicitis. Normally the mucosal layer is packed with lymphocytes, eosinophils and an occasional neutrophil. In cases in which obstruction is present, owing to the very small caliber of the mucosal vessels, distention early produces pressure necrosis. Sections through distended appendixes show flattening, thinning and patchy sloughing of the mucosa distal to the obstruction, while proximally the mucosa is of normal thickness. It is true that the area immediately surrounding the fecalith may show the greatest pressure necrosis, but the perforation rarely is seen at a point over the fecalith. The theory held by the German school is that pressure necrosis causes perforation, but this mechanism was found to operate in only 2 cases in this series. As soon as there is patchy desquamation of mucosa due to pressure, submucosal tissue is exposed to bacterial invasion, and a heavy cellular exudate develops at this point. This may be what German authors (Schrumpf [89]; Noll [90]) have described as a pseudodiphtheritic type of membrane in cases of appendicitis. In the nonobstructive type of appendicitis a mucosal lesion is presupposed as a precursor to bacterial invasion, but, as Aschoff admitted, it usually is impossible to demonstrate. In this series such a lesion was shown in 1 instance, in which

89. Schrumpf, P.: Beiträge zur pathologischen Anatomie der Wurmfortsatzerkrankungen, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **17**:167-209, 1907.

90. Noll, R.: Die Histologie der Wurmfortsatzentzündung, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **17**:249-348, 1907.

there was mucosal ulceration at the point where a sharp spicule of bone in the lumen pierced the appendical wall. In the other cases neutrophilic infiltration was the only significant change. In the cases of appendectomy after an interval no uniform mucosal changes could be demonstrated. Areas of mucosal denudation tend to heal by obliteration of the lumen in that region, so that small cystic areas frequently are seen at a later date. In some cases the appendix is represented by a fibrous cord and a small terminal cyst. Healing by fibrosis results in irregular contractures with distortion of the lumen. Spencer [91] found 75 per cent of acutely diseased appendixes to be bent as a result of fibrosis. In some cases the reaction may be extremely cellular, so that the mucosa becomes hyperplastic and is thrown into abnormally thick folds.

The submucosa, since it carries most of the larger vessels, is important in the development of acute inflammation. There has been considerable discussion as to the site of origin of the initial lesion in appendicitis, but it is obvious that the cellular exudate must reach the appendix by way of the blood stream, so that the most vascular layer will first show accumulation of fluid and neutrophils. In addition to being most vascular, the submucosa normally is composed of a loose connective tissue stroma, which lends itself to accumulation of fluid and cells. In the early stages of appendicitis the submucosa may be the first layer to show edema and neutrophilic infiltration, which begin around the walls of vessels. Margination of leukocytes in the vessels, due to vascular stasis coincident to obstruction, is also seen. These changes are most prominent and widespread in cases in which the disease is due to obstruction, for in cases in which bacteria play a part there is one focus about which inflammation centers while in the presence of obstruction all tissue distal to the obstruction shares about equally in the developing inflammation. Usually this picture was clearly evident, but in some cases it was obscured by the normal accumulation of lymphoid tissue in the submucosa. In cases of appendectomy after an interval, as has been mentioned, the submucosa showed infiltration with lymphocytes, eosinophils, plasma cells and new connective tissue cells. In some instances the layer was extremely fibrotic, and by the use of special stains collars of lymphocytes and fibroblasts could be seen around the submucosal vessels.

The lymphoid tissue usually shares but little in the changes incident to the development of acute inflammation. In this series, both in normal appendixes and in appendixes removed after an interval, the lumen frequently was filled with lymphocytes; it was concluded, therefore,

91. Spencer, A. M.: Aetiology of Acute Appendicitis, Brit. M. J. **1**:227-230, 1938.

that the lymphoid follicles periodically discharge their contents into the lumen. This belief has been shared by Thompson,[92] who demonstrated it in the exteriorized appendixes of rabbits. This periodic rupture may allow bacterial invasion, and Schrumpf [89] observed abscesses of the lymph follicles in cases of so-called catarrhal appendicitis. Noll [90] also cited this etiologic mechanism. It was observed once in this series. In cases of appendicitis due to obstruction there were no definite changes in the lymphoid tissue. In the series of cases of appendectomy after treatment, the lymphoid tissue usually was much decreased, probably as a result of the contracture associated with fibrosis.

The muscularis is resistant to distention and because of its density is infiltrated with leukocytes rather late in the course of appendicitis. In the early stages, whether the disease is obstructive or bacterial in origin, there are usually no changes in this layer. In the cases of the obstructive type the muscularis is one of the strongest barriers to perforation. As it becomes thinned by distention and the muscle fibers are separated by accumulation of inflammatory exudate, the continuity of this layer is broken and a microscopic diagnosis of gangrene is made. From this it is seen that a diagnosis of gangrene is not necessarily made from the gross specimen. In cases in which obstruction is not present the inflammatory exudate accumulates, but since there is no distention the layer does not become thinned. This explains in part why perforation is rare in such cases. Obstructed appendixes become distended and thinned, while nonobstructed appendixes are thick walled and soggy with accumulated fluid and cellular exudate. This point is sufficiently characteristic to make the diagnosis of obstruction possible on examination of the section only. In the cases in which an interval preceded operation, as has previously been noted, the muscularis may have appeared normal in the ordinary section but staining with azocarmine showed marked fibrosis.

The serosa normally contains a rather rich supply of lymph spaces and blood vessels, so that it enters prominently into the changes incident to inflammation. In cases of appendicitis due to obstruction it may show edema and neutrophilic infiltration as early as the submucosa. However, if these changes are seen only in the serosa, a diagnosis of periappendicitis is indicated, as intraperitoneal lesions, particularly those occurring in the pelvic organs of the female, give rise to serositis without involvement of the deeper layers. In cases in which there is no obstruction the serosa shows infiltration with fluid and cells to a degree no less marked than that associated with obstruction. In the series in which operation was delayed the serosa on ordinary stain-

92. Thompson, H. G.: Lymphoid Tissue of the Alimentary Canal, Brit. M. J. **1**:7-11, 1938.

ing showed more marked and constant changes than any other layer. There were always marked increase in vascularity, lymphocytic foci and irregular thickenings of the serosa. These changes represent the end stages of healing of the surface exudate and are closely connected with the process of periappendical formation of adhesions.

The mesoappendix is early the seat of edema and neutrophilic accumulation in obstructive appendicitis, as a result of distention and vascular stasis. Schrumpf [89] and Noll [90] also found this to be true. They noted frequent thrombosis of the mesenteric veins in cases of severe involvement, but this has not been observed in this series, although search has been made. In the cases in which there is no obstruction thrombosis of the mesenteric veins is more rarely seen, but has greater significance in that these thrombi are more likely to be infected. This is the most plausible source of abscesses of the liver as a complication of appendicitis. Microscopic sections in cases in which an interval preceded appendectomy showed the same type of fibrosis, vascularity and lymphocytic infiltration in the mesoappendix as in the serosa.

Tabulation of the details of the microscopic pathologic picture in 68 acutely diseased and gangrenous appendixes, both of the obstructive and the nonobstructive type, gives the following information:

1. There is no correlation between the duration of the disease process and the severity of the pathologic change. Apparently the important factor is the severity of the infection or the completeness of the obstruction rather than the number of hours of duration. For example, in 1 case the appendix, obstructed by a fecalith, became gangrenous and ruptured in eight hours, while in another, in which there was also obstruction by a fecalith, only mild inflammation was seen after ninety-six hours.

2. Distention of the lumen and flattening of the mucosa by pressure are the two most reliable observations in the obstructed appendix and readily distinguish the obstructive from the bacterial type of the disease, as in the latter there never is distention of the lumen or thinning of the wall.

3. The mucosa in both the obstructive and the bacterial type may be necrotic and sloughing, but in the obstructed appendix the mucosa is thinned by pressure, while in the infected organ the mucosa is thickened, owing to edema and infiltration.

4. The type of cellular exudate is identical in the two varieties of appendical inflammation. The only differential point seems to be the thinning of the wall and dilatation of the lumen in the obstructive type, as a result of distention and increased intraluminal pressure.

8. *Micrometry of Appendical Wall and Lumen.*—Throughout this paper it has been emphasized that distention of the lumen and thinning

of the wall are found distally in the obstructed appendix. In order graphically to emphasize this important point, 75 specimens were selected from normal, acutely diseased and gangrenous appendixes in cases of obstructive and nonobstructive appendicitis. These appendixes all had been fixed, then split longitudinally and mounted in paraffin before sectioning and staining. Micromeasurements were made of the thickness of the wall and the width of the lumen, both distal and proximal, a Filar micrometer calibrated against a hemocytometer chamber being used. These measurements clearly showed the phenomenon of distal distention in the cases in which obstruction was present. The normal appendixes showed practically no difference (20 microns) between the thickness of the wall at the base and that near the tip of the appendix. The lumen was shown to be moderately bulbous, being about three times as large toward the tip. In nonobstructed specimens the wall was increased in thickness by about one fourth, and the greatest increase was near the base. This increase in thickness represented infiltration with fluid and leukocytes. There was surprisingly little difference (about 20 microns) between the cases of nonobstructive acute appendicitis and those of the nonobstructive gangrenous type. The lumen showed moderate increase in width, owing to accumulation of pus. In the obstructed specimens the walls showed marked thinning distal to the point of obstruction. In the gangrenous obstructed appendixes the thickness of the distal portion of the wall was about one third that of the proximal portion and the diameter of the lumen toward the tip was more than three times as great as that near the base and more than ten times the normal size. These observations are strikingly brought out in figure 8.

9. *Gross Pathologic Picture.*—Inspection of the appendix in the earliest stages of inflammation may reveal nothing more than increased turgidity due to edema. Slightly later there are engorgement and tortuosity of the serosal vessels, due to the hyperemia of infection or to the venous stasis of early distention. Up to this time the obstructed and the nonobstructed appendix may have an identical gross appearance except that in the former an obstructive mechanism may be seen or palpated. Later, however, there is a marked difference in the appearance of the two types. The obstructed appendix always becomes more or less tensely distended distal to the point of obstruction, and there is a sharp transition to normal tissue proximal to this point. Distally the thinning wall becomes covered by a shaggy green to yellow fibrinous exudate, which is absent proximal to the obstruction. Proximally only edema and congestion are noted. The omentum or the adjacent loops of small bowel often become adherent to the area of exudate. The gangrenous obstructed appendix is friable, tensely distended and often

surrounded by a cloudy to purulent fluid, which may be sterile. With perforation, the distal portion, which is gangrenous, may slough off into the resulting abscess cavity. After the distention is relieved by perforation it may be difficult or impossible to demonstrate an obstructing mechanism. At the operating table such conditions as kinks, adhesive bands and a retrocecal position may be recognized and evaluated as causes of obstruction, but often in their absence it is necessary to "bivalve" the fixed appendix longitudinally in order to determine whether obstruction to the lumen exists. In the nonobstructed specimen

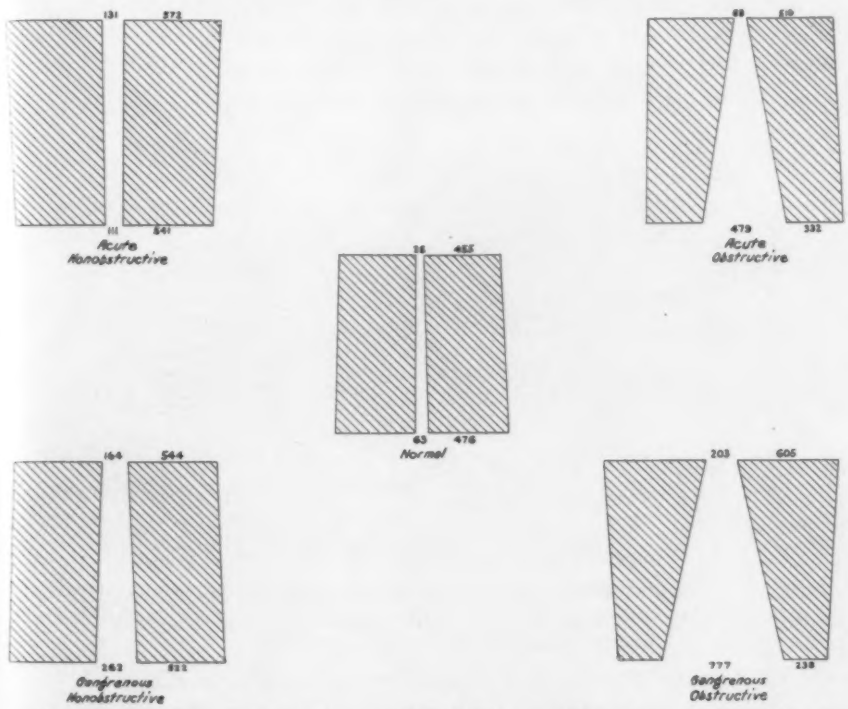

Fig. 8.—Micrometric data in a series of 75 appendixes from the normal, the acutely diseased nonobstructed, the gangrenous nonobstructed, the acutely diseased obstructed and the gangrenous obstructed groups. Measurements were made of the width of the lumen and of the thickness of the wall, both distally and proximally. The average for each group was determined, and this chart is a graphic representation of the data, drawn to scale. The effect of distention on the wall and on the lumen distal to the point of obstruction is clearly shown. Note that the changes are observed most clearly on longitudinal section. External inspection of the obstructed appendix does not reveal these changes, because the external diameter is fairly constant throughout the length of the organ.

a thick, congested, soggy wall without distention of the lumen or thinning of the wall usually is seen. Otherwise the appearance is similar to that described for the obstructed specimen.

10. *Healing.*—Healing in appendicitis is accompanied by replacement by fibrous tissue of all structures destroyed by the inflammatory reaction. The changes include: (1) obliteration of the lumen if the mucosa is destroyed by ulceration; (2) fibrosis of the submucosa; (3) fibrosis of the musculature, with consequent dysfunction, and (4) thickening, irregularity and increased vascularity of the serosa. The following experiment was undertaken in order to study the microscopic evidences of healing: Forty-three appendixes were chosen, as follows: 7 microscopically normal, 3 acutely diseased, 3 gangrenous, 6 obliterated, 11 "interval" specimens and 13 animal specimens. The sections were stained with hematoxylin and eosin and with azocarmine to show fibrous tissue. The normal appendixes were studied in order to establish a standard for comparison. In the acutely diseased appendixes the serosa

Fig. 9.—Photomicrograph of a longitudinally sectioned appendix removed in the interval between attacks. This section shows the distal portion of the appendix to be fibrotic and without a lumen or epithelial elements.

was edematous and contained new connective tissue. The muscle fibers were separated by new connective tissue fibrils, and the submucosal vessels were surrounded by collars of new connective tissue and lymphocytes. The gangrenous specimens showed a large amount of fibrinous exudate in all layers, in addition to a dense cellular infiltration throughout the organ. The obliterated appendixes contained a central fibrous core without epithelial elements. In many instances the muscularis was fibrotic, and the muscle fibers were separated into small isolated masses. In some instances there were fibrous tissue collars around the vessels (fig. 9). The most striking changes were noted in the "interval" specimens, which were characterized by submucosal fibrosis with perivascular collars, fibrosis of the muscularis and serosal thickening with new connective tissue, lymphocytic foci and abnormal

vascularity. In the animal group, specimens showing acute changes, gangrene and various stages of healing were chosen and studied with the azocarmine stain. The results paralleled in all particulars the observations on the clinical material.

11. *Organic Residual Changes.*—The actual organic residual changes of appendicitis include obliteration, stenosis, fibrous septums dividing the lumen into locules, mucocele formation, diverticula and granulomatous thickening of the wall. Letulle [93] mentioned all of these changes as being due to previous inflammation. The controversy as to whether obliteration represents healed inflammation or a normal physiologic process of age will not be discussed in this paper.

Many bizarre observations are reported in the literature; for example, Berger and Simon [94] reported a case in which the appendix had been amputated spontaneously and was lying free in an abscess cavity. Piraja [95] reported a case in which the inflamed tip had eroded through the posterior aspect of the cecum, and at subsequent operation the appendix was observed to have two cecal orifices.

Peterson [96] stated that 172 cases of mucocele of the appendix have been reported. These reports have usually dealt with large cysts, and no doubt many hundreds of instances of smaller ones have not been reported. If obliteration of the lumen occurs first at the base, rather than at the tip, a closed cavity is formed. The organisms gradually die out, and the sterile cavity slowly increases in size, owing to accumulation of mucus. This slow increase in size does not embarrass circulation, so that no acute inflammatory process develops. Josa [97] observed B. coli in a mucocele but expressed the belief that the cavity gradually tended to sterilize itself. Horsley and Warthen [98] concurred in these views. Collins [99] observed at autopsy an incidence of obliteration of 39 per cent in a series of 1,054 appendixes. In 3 per cent the obliteration

93. Letulle, M.: Les surprises de l'appendicite chronique, Presse méd. **35**:1521-1523, 1927.

94. Berger, J., and Simon, R.: Evolution vers la résorption d'un appendice amputé spontanément et flottant dans un abcès, Bull. et mém. Soc. nat. de chir. **60**: 1026-1029, 1934.

95. Piraja, O.: Appendice cecal com dupla implantacao, Ann. paulist. de med. e cir. **27**:233-239, 1934.

96. Peterson, R. F.: Mucocele of the Appendix; Report of Two Cases, Northwest Med. **23**:328-330, 1934.

97. Josa, L.: Ueber einen seltenen Fall von Appendicitis phlegmonosa im oblitierten Wurmfortsatz, Zentralbl. f. Chir. **62**:259-262, 1935.

98. Horsley, J. S., and Warthen, H. J., Jr.: Pathogenesis and Symptoms of Chronic Obliterative Appendicitis, Ann. Surg. **96**:515-529, 1932.

99. Collins, D. C.: Mechanism and Significance of Obliteration of the Lumen of the Vermiform Appendix, Ann. Surg. **104**:199-211, 1936.

began at some point other than the tip. That residual organic changes tend to follow appendicitis is shown by the following tabulation:

	Acute Appendicitis		Gangrenous Appendicitis		Appendectomy After Interval		Gynecologic Group	
	Cases	%	Cases	%	Cases	%	Cases	%
Residual changes	5	5	8	10	50	34	7	12

The number of cases in which the various residual changes were observed were as follows:

	Acute Appendicitis	Gangrenous Appendicitis	Appendectomy After Interval
Obliteration	2	0	25
Stricture	4	0	13
Fibrous septums	0	7	0
Adhesive bands	1	5	0
Kink	1	5	0
Mucocele	0	0	2
Diverticulum	0	0	2

It is of interest to note that in the cases of acute and gangrenous appendicitis due to obstruction there was an incidence of organic residual changes of 28 per cent as compared with the absence of such changes in the cases in which obstruction was not present (fig. 10).

In these studies many interesting observations have been made in the microscopic sections. In 5 of the cases of appendectomy after an interval the area of previous perforation could be visualized clearly. The accompanying photomicrograph is illustrative (fig. 11). In 2 cases a lymphoid follicle had acquired a pedicle and had become polypoid. In 1 case of the acute form there was a definite abscess in the wall of the appendix, and in 1 case a fecalith was being pushed through a perforation in the appendix. In 2 other cases there were high polypoid mucosal rugations.

In every case in this series the inflammatory process was most severe toward the tip of the appendix. In no case was there basal gangrene with a noninflamed tip. Orthner,[100] on the other hand, reported an incidence of basal gangrene of 2 per cent in otherwise normal appendixes. He stated that this condition is usually symptomless and that perforation takes place before the diagnosis can be established. Handley[101] described a similar process in which perforation occurs into the fatty layers between the leaves of the mesentery. This leads to spreading retroperitoneal cellulitis rather than to peritonitis and is not accompanied by rigidity or other signs of peritonitis. This phenomenon is rare in man, but is seen frequently in the dog. It is most often due to perforation through the bowel into the mesentery by a foreign body in the lumen.

100. Orthner, F.: Die basale Gangren des Wurmfortsatzes, Schweiz. med. Wchnschr. **65**:92-93, 1935.

101. Handley, W. S.: Basal or Cellulitic Appendicitis, Clin. J. **64**:1-3, 1935.

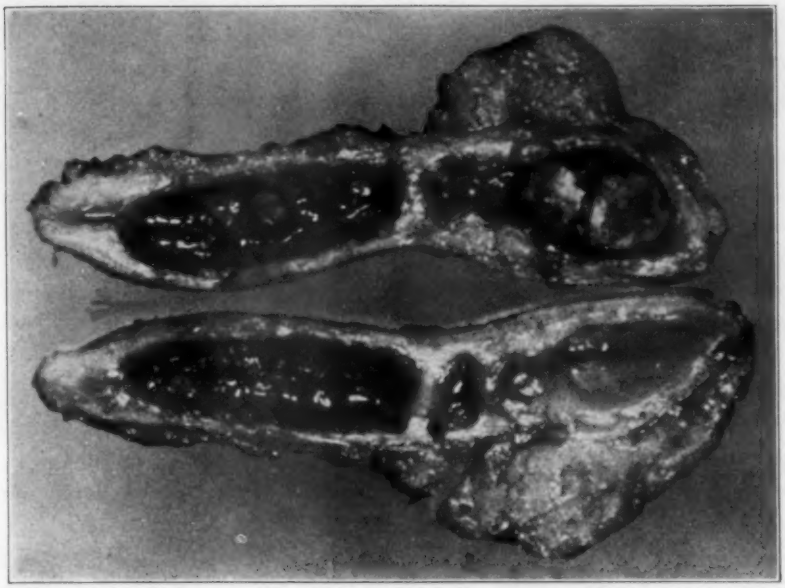

Fig. 10.—Appendix showing the fibrous septums resulting from previous attacks of appendicitis and partially dividing the lumen into three distinct compartments, two of which contain fecaliths. The small fecalith is not shown in the original position of impaction, but it will be noted that the lumen proximally is normal in caliber and the walls are of normal thickness.

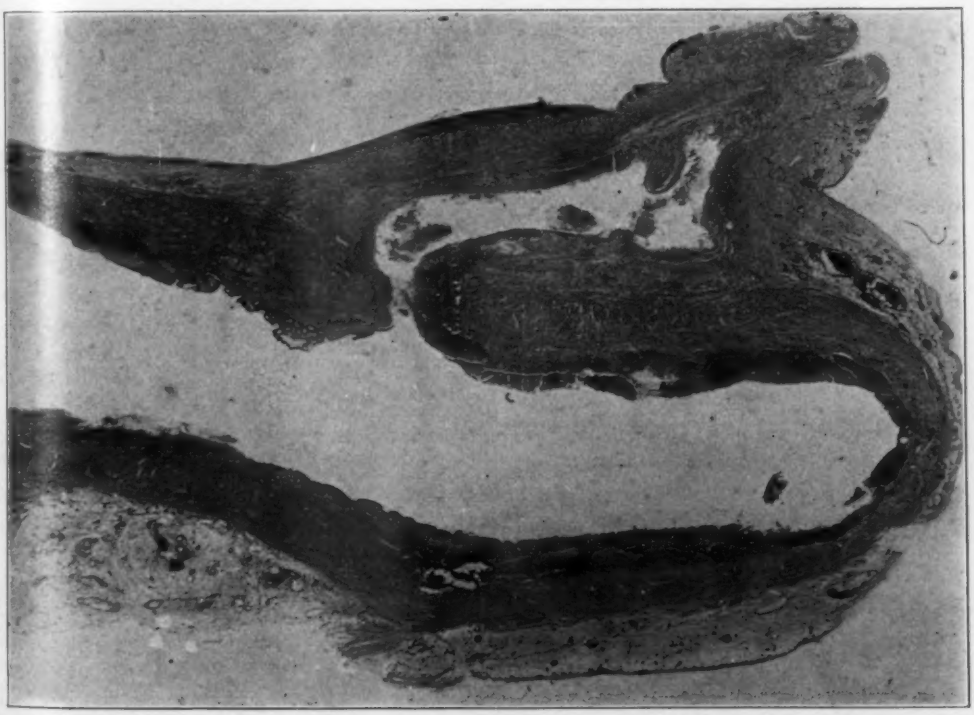

Fig. 11.—Appendix removed six weeks after the original perforation. It can be seen that the defect in the wall has not healed but has been covered by exuberant granulation tissue and infected, edematous serosa. A slight increase in intraluminal pressure would readily initiate a second perforation, with peritoneal soiling.

(*a*) Colic Group: In the Minneapolis General Hospital series there were 5 cases which have been considered in a separate group. In these cases (the patients were all girls, with an average age of 19 years) the average duration of appendicitis, of mild type, was one hundred and twenty hours. Nausea and constant pain were present in 81 per cent, with vomiting and rigidity in half that number. All the patients had pain in the right lower quadrant, and 60 per cent had rebound tenderness. Sixty per cent gave a history of similar previous attacks. The average temperature was 99.8 F., the average pulse rate was 86 and the average white blood cell count was 11,825, with 73 per cent neutrophils. These 5 girls were operated on, and in each case the appendix was microscopically normal, without any signs of present or past inflammation. However, there was an obstructing fecalith in every case, and in 80 per cent a distally dilated lumen gave evidence of some increased intraluminal pressure. In 40 per cent there were bacteria in the tissues. The condition in these cases was the so-called colic type of appendicitis, which is to be explained on one of the following bases: 1. It may represent simply a mild form of closed loop with incomplete obstruction, so that the more severe late effects are absent. 2. It may be caused by purely mechanical factors, the musculature contracting in an effort to expel the fecalith and producing the same type of pain as that seen in intestinal obstruction in which the intermittent peristalsis causes cramp-like pains. All of the patients were relieved by appendectomy. This is illustrative of the fact that removal of a microscopically normal appendix may cure the patient. Pathologists as yet have no way of classifying such dysfunction and are apt to criticize a surgeon for removing a so-called normal appendix. Mayo [102] also has shown that removal of the appendix in 100 cases of obscure pain in the right lower quadrant gave relief in 70 per cent.

12. *Periappendicitis.*—Periappendicitis, as described by Gordon,[103] is an inflammatory change limited to the serosa and due to pelvic inflammatory disease or to some other peritoneal infection. In 62 appendixes removed incidental to some gynecologic procedure,[104] there was an incidence of periappendicitis of 16 per cent. This condition is symptomless because there is no distention, and often is not diagnosed

102. Mayo, C. W.: Exploration of Abdomen and Appendectomy for Atypical Symptoms: Results Five Years After Operation in One Hundred Cases, West. J. Surg. **42**:189-190, 1934.

103. Gordon, H.: Periappendicitis Without Appendicitis: Study Based on 26,051 Appendixes, Arch. Path. **19**:185-202 (Feb.) 1935.

104. Shute, E.: Invagination of Appendical Mucosa Producing Symptoms Resembling Appendicitis, Arch. Surg. **27**:75-82 (July) 1933.

on examination of the gross specimen. In 11 per cent of the specimens there were bacteria in the superficial tissue layers, and in 10 per cent, over the surface of the serosa. In 25 per cent of cases there were fecaliths in the lumen, but in only 1 per cent were there evidences of actual obstruction. This emphasizes the harmlessness of fecaliths in the absence of obstruction to the lumen. This was brought out most clearly in an autopsy specimen in which there was a large fecalith in the tip of the appendix. There was no remaining mucosa around this fecalith, which was completely walled off by fibrous tissue. There

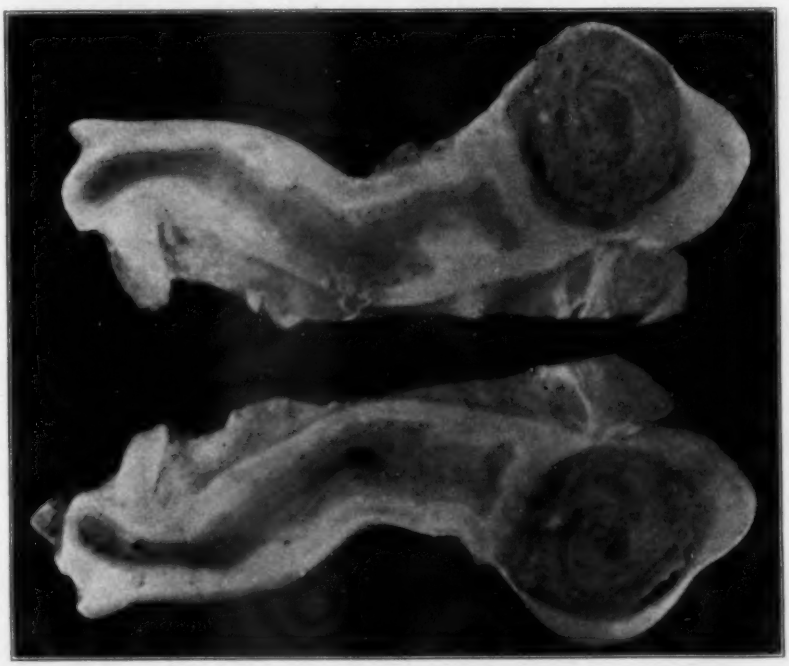

Fig. 12.—Autopsy specimen. The illustration shows why some fecaliths may be present for years without initiating acute appendicitis. The fecalith has destroyed the surrounding mucosa by pressure and now is actually walled off and lies distal to the termination of the lumen. Since there is no obstruction and the fecalith is not surrounded by a secreting mucosa, no distention develops and there is no inflammation, although there are bacteria distally in the tissues, as seen in a Gram tissue stain.

could be no harmful effects because in the absence of a secreting mucosa distention could not develop. The Gram stain showed organisms in the fecalith and around its edges, with some in the tissues (fig. 12).

Periappendicitis was seen in 5 autopsy specimens. One was obtained in a case of dysentery with perforation of ulcers of the colon and

peritonitis. The appendix showed acute serositis with mixed organisms in the serosa. Another specimen was from a patient who died of perforation of a duodenal ulcer. A third was from a patient with postoperative peritonitis, and the other 2 were from patients with primary pneumococcic peritonitis. These last specimens showed gram-positive diplococci in the serosa.

APPENDICOLITHS

1. *Incidence.*—In this series the incidence of fecaliths for the entire group of cases of acute appendicitis was 67 per cent, and in 16 per cent of these cases there were multiple stones. In no case was

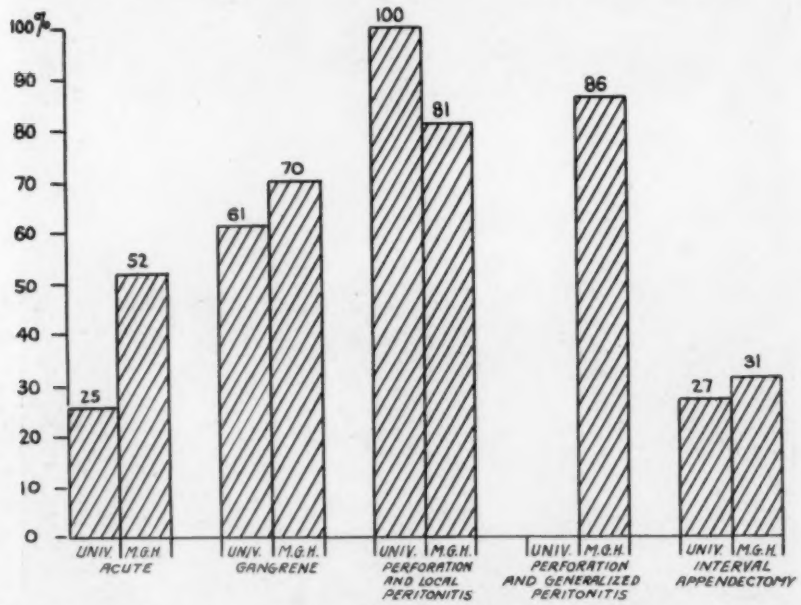

Fig. 13.—Incidence of fecaliths in the various types of appendicitis in this series.

inspissated fecal material (fig. 13) classed as a stone. The incidence of appendicoliths was distributed among the groups as follows:

	Acute Appendicitis		Gangrene		Localized Peritonitis		Generalized Peritonitis		Colic		Appendectomy After Interval		Gynecologic Group	
Minneapolis	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	%
General Hospital.....	25	52	14	70	10	81	19	86	5	100	5	31	3	10
University Hospitals.....	11	25	35	61	4	100	..	..	..	..	35	27	13	40
Average.....		38		65		90		86		100		29		25

2. *Microscopic, Chemical and Roentgenographic Data.*—Roentgenograms of these appendicoliths were taken routinely, and all showed laminations due to successive concentric deposits (fig. 14). Many of the stones were sectioned and examined microscopically. In every case there was a large amount of cellulose material (fig. 15). The

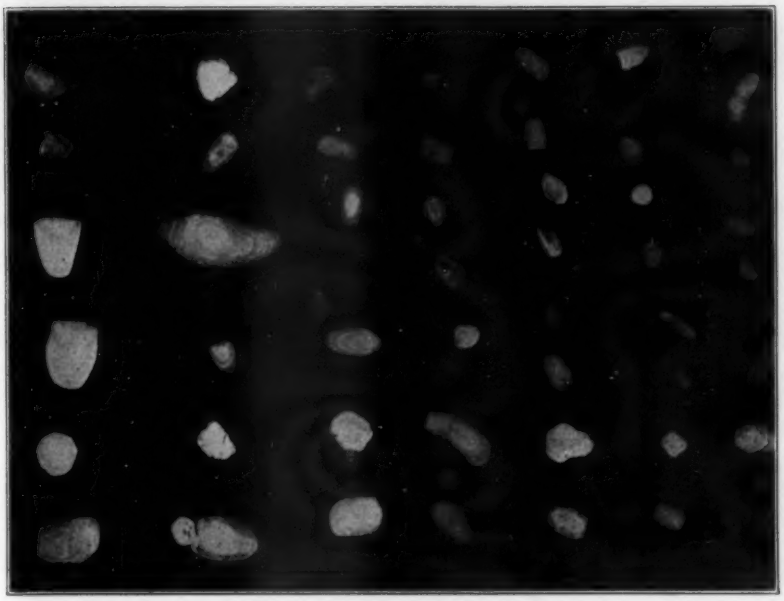

Fig. 14.—Roentgenogram of a group of fecaliths, demonstrating their laminated structure. This indicates that they probably form in situ but does not give any suggestion as to their age, as the rapidity with which laminas are laid down is not known.

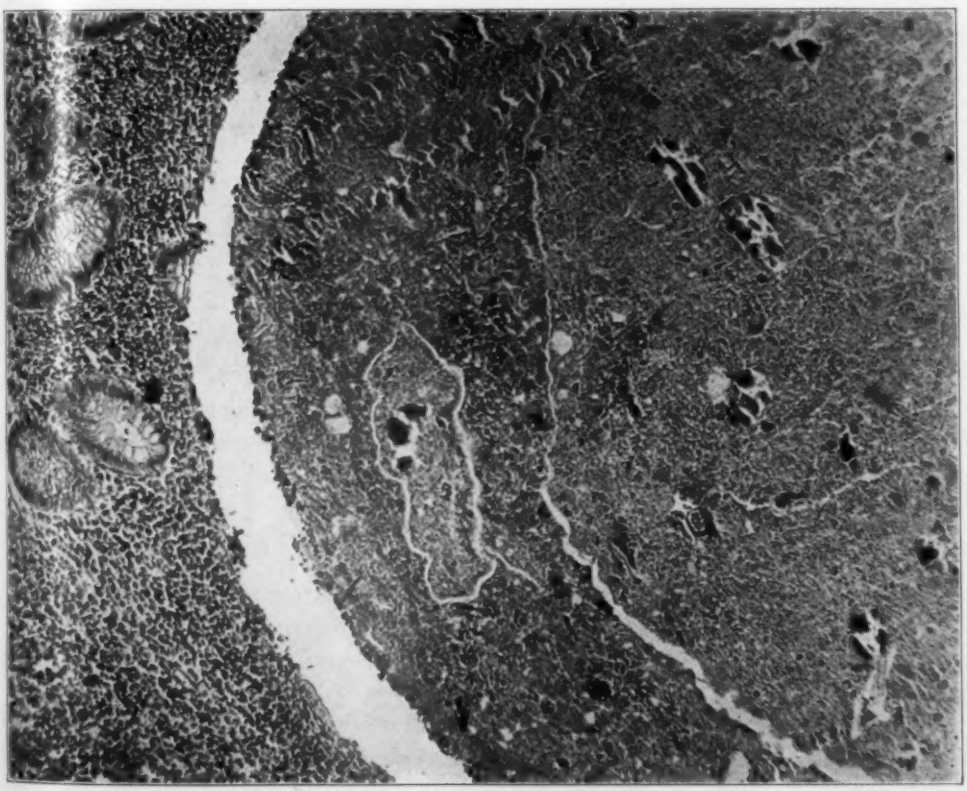

Fig. 15.—Photomicrograph showing the laminated character of a fecalith. The densely stained areas are calcium. Masses of cellulose and amorphous material are seen to make up the greater portion of the stone.

Gram stain revealed dense masses of bacteria throughout the concretion. There usually was a central nidus, which was often a mass of cellulose. Parasites were seen in a number of fecaliths, but this has been discussed previously. In 4 cases blueberry seeds (Vaccinium pennsylvanicum) formed the nidus and were identified on microscopic section (fig. 16). On questioning, 1 of the patients was positive that she had not eaten blueberries for over two years. This probably was inaccurate, but at least it indicates a long period of stasis in the appendix. In 3 cases small brown shiny faceted stones, resembling gallstones, were observed

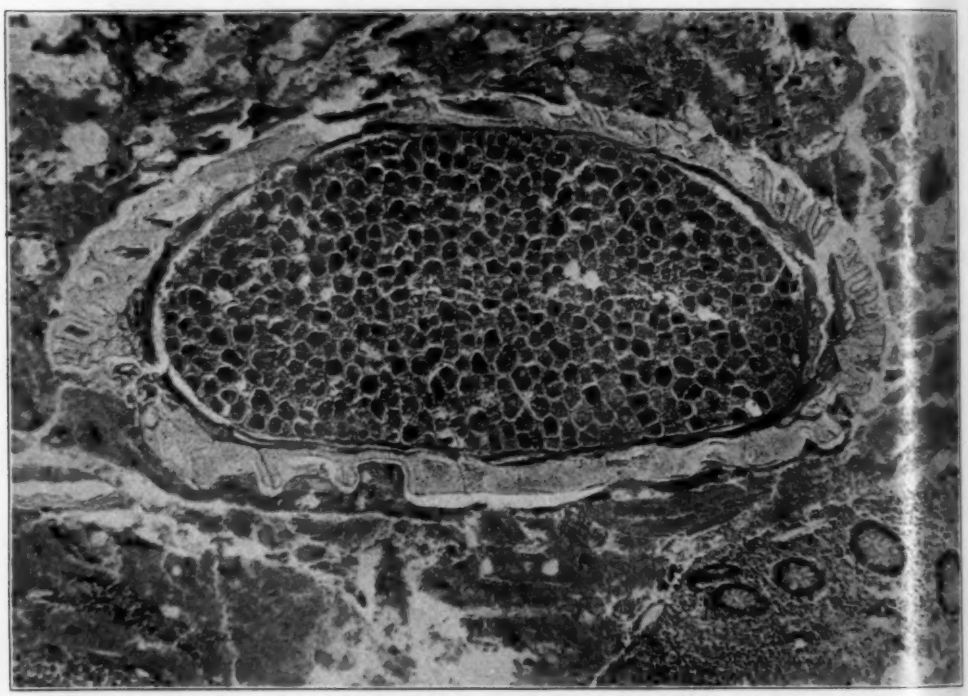

Fig. 16.—Photomicrograph of a blueberry seed within a fecalith in an appendical lumen. This illustrates how such foreign bodies may form a nidus about which a fecalith is deposited in successive laminas.

in the appendix, and in 1 case these stones seemed to be identical with those removed from the gallbladder at the same time.

An attempt was made to determine the nature of the pigment in appendicoliths. Chemical tests for bilirubin, biliverdin, urobilin and urobilinogen on several occasions all gave negative results. In view of the high calcium content of the stones, as will be shown later, it is probable that the pigment is a calcium salt of one of the reduced forms of bile pigment, probably kopronegrin.

A group of fecaliths was analyzed for organic and inorganic material. A group of scybalous masses of normal stool was similarly analyzed for comparison. Table 5 shows the comparative results.

There are two types of appendicoliths: those which are hard, white and odorless and those which are softer and brown and have a fecal odor. Both types are laminated and radiopaque and usually have a central nidus composed of cellulose, parasites or foreign bodies, such as seeds, bristles, pins or enamel from kitchenware.

It is impossible to state the normal incidence of fecaliths, but there are a number of references to their frequency in inflamed appendixes. Fitz [3] reported an incidence of 47 per cent of fecaliths and 12 per cent of foreign bodies in a series of 152 cases of appendicitis and stated that in about 60 per cent of all cases perforation is caused by fecaliths

TABLE 5.—*Chemical Analysis of Fecaliths* *

	Fecaliths, %			Stool Nuggets, %		
	Original	Dried	Ash	Original	Dried	Ash
Calcium	8.04	12.98	33.04	4.10	4.39	29.33
Phosphorus	4.39	7.07	18.07	2.01	2.15	14.35
Magnesium	0.80	1.29	3.28	0.8	0.86	5.74
Sulfur	0.0	0.0	0.0	0.74	0.80	5.30
Chlorine	0.0	0.0	0.0	0.12	0.125	0.83
Volatile material at 110 C		37.82			6.91	
Ash: Original		24.32			13.98	
Dried		29.12			14.98	
Free lipoids		13.93				
Fatty acids		3.35				
Free cholesterol		6.65				

* The results of this analysis indicate that the fecalith is not merely inspissated feces but is a definite concretion.

or foreign bodies. He cited Matterstock as finding 53 per cent of fecaliths and 12 per cent of foreign bodies in a series of 169 cases of fatal perforative appendicitis. Aschoff,[13] in 1905, said that in most cases appendicitis occurs in the stone-free appendix, but this observation does not hold true for the series of most investigators. He stated that fecaliths are harmless unless infected, but most observers find it difficult to conceive of a sterile fecalith. In his monograph, published in 1908, Aschoff [57] gave the following data:

	52 Cases of Normal Appendicitis	177 Cases of Appendectomy After Interval	126 Cases of Acute Appendicitis
Feces	62%	62%	10%
Fecaliths	6%	12%	27%

These figures are extremely low as compared with those of other observers, although Burgess [31] found that only 21 per cent of 500

appendixes contained fecaliths. He observed fruit seeds in several and pinworms in many. Williams and Boggon [82] reported that 39 per cent of appendixes with an acute condition contained fecaliths.

The general impression is that appendicoliths form in situ, successive laminas being deposited about some extraneous nidus. This impression is based on the fact that the concretions frequently reach the size of walnuts (Wells [105]), being much larger than the lumen of the appendix,

Fig. 17.—Scout roentgenogram of the abdomen in the case of a 19 year old youth who had a history of nausea and vomiting of forty-eight hours' duration, accompanied by tenderness, rebound tenderness and rigidity in the right lower quadrant of the abdomen. There had been no previous attacks. The temperature was 101 F., the pulse rate 92 and the leukocyte count 11,500 per cubic millimeter, with 82 per cent neutrophils. A mass 5 cm. long was palpable in the right lower quadrant. The plate shows one large and one small fecalith, easily recognizable by the concentric lamination. A tensely distended, gangrenous, obstructed appendix was removed, and the fecaliths were recovered. The palpable mass might be mistaken for regional enteritis, but the scout roentgenogram clinches the diagnosis of appendicitis, as ureteral stones are not laminated in this way.

105. Wells, C. A.: Appendix Concretions Opaque to X-Rays, Brit. M. J. **2**: 1041-1042, 1930.

and that all fecaliths are made up of concentric laminations about some central mass (figs. 17 and 18) of foreign material (Volz [1]).

It is a common observation that sections of fecaliths show large quantities of cellulose. Maver and Wells [106] demonstrated sclerous vegetable material, granules of silicates and occasional parasitic ova. These authors analyzed several groups of fecaliths, and they found one half of the material by weight to be soluble in fat solvents. This was chiefly soap, although there was some koprosterol and a little cholesterol. About one fourth of the total weight was composed of inorganic salts, chiefly calcium phosphate, and about one fifth of the total weight was

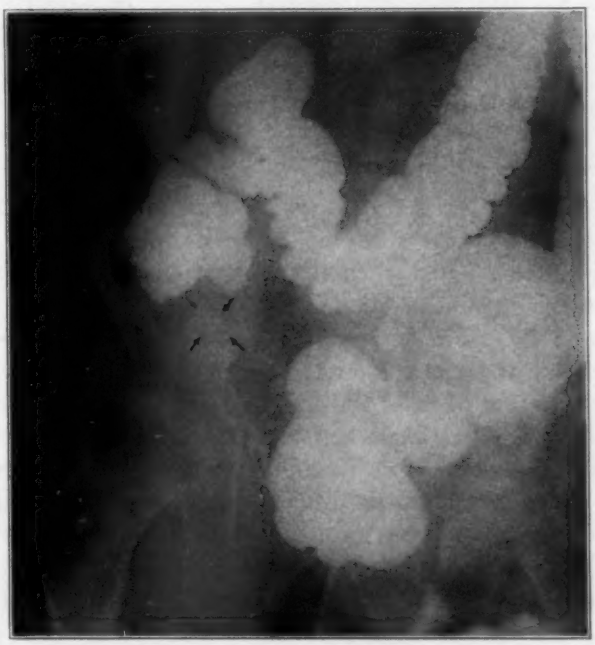

Fig. 18.—Roentgenogram taken after a barium enema in the case of a 56 year old man who gave a history of repeated abscesses in the lower right quadrant of the abdomen following rupture of the appendix. A large, laminated fecalith is seen below the cecum and in the region of the abscess, which deforms the base of the cecum.

organic residue, mostly vegetable fibers from the cecum. It is to be noted that bile pigments and bile acids usually are absent.

3. *Foreign Bodies.*—Several interesting foreign bodies were observed in the appendixes studied. In 1 case the appendical lumen contained a small spicule of bone, which was piercing the wall. The lumen

106. Maver, M. E., and Wells, H. G.: Composition of Appendiceal Concretions, Arch. Surg. **3**:439-444 (Sept.) 1921.

contained pus. In another case the lumen contained a piece of keratinized material resembling finger nail. In a third instance a tooth-brush bristle was seen in the lumen.

CLINICAL MANIFESTATIONS

1. *Symptoms.*—(*a*) Average Hours of Duration: As would be anticipated, the average duration of symptoms, in terms of hours, is correlated with the severity of the disease process. In this series appendicitis due to obstruction tended to have a shorter course (twenty-three hours) than the nonobstructive condition (thirty-two hours). The following data show the average number of hours of duration for the various types.

	Acute Appendicitis	Gangrene	Localized Peritonitis	Generalized Peritonitis
Minneapolis General Hospital...	59 hr.	36 hr.	79 hr.	76 hr.
University Hospitals.....	43 hr.	31 hr.	24 hr.	.....
Average.....	51 hr.	33 hr.	51 hr.	76 hr.

It will be noted that in the cases of acute appendicitis the duration was longer than in the cases of gangrene. This is because acute appendicitis is less severe than the gangrenous type, and the patient postpones seeking medical aid.

(*b*) Pain: The pain of acute appendicitis is of two types, constant and colicky. In the average for the entire series, the colicky type was found in 31 per cent of cases and the constant pain in 56 per cent. This difference is more striking when the cases are divided according to the presence or absence of obstruction. In cases of the nonobstructive type colicky pain was found in 32 per cent and constant pain in 33 per cent, whereas in cases of the obstructive type colicky pain was present in only 12 per cent and constant pain in 74 per cent.

(*c*) Nausea: This symptom is much more frequent in acute appendicitis than vomiting, the former being seen in 90 per cent of cases and the latter in 68 per cent. In cases of the obstructive type, nausea was found in 81 per cent and vomiting in 64 per cent. In cases of the nonobstructive condition nausea was observed in 88 per cent and vomiting in 58 per cent.

(*d*) Constipation: This condition was present in 13 per cent of cases in this series, and there was no apparent correlation between this factor and obstruction.

2. *Physical Signs.*—(*a*) Tenderness: The most frequent finding in acute appendicitis is tenderness, which was elicited in 98.5 per cent of all cases. There is no significant difference in the obstructive and the nonobstructive type in this regard.

(*b*) Rebound Tenderness: The next most frequent physical sign is rebound tenderness, which was present in 87.5 per cent of all cases

in this series. In this respect there was an appreciable difference between the obstructive and the nonobstructive type, the incidence in the former being 75 per cent and that in the latter 59 per cent.

(*c*) Rigidity: Rigidity was elicited in 85 per cent of cases. In the cases of obstructive appendicitis rigidity was demonstrated in 92 per cent, and in those of the nonobstructive type, in 68 per cent.

(*d*) Murphy's Sign: The Murphy sign is pain in the right lower abdominal quadrant caused by pressure of the hand on the left lower quadrant, and it depends on pressure of abdominal organs or colonic contents on the inflamed appendix. This sign was positive in 29 per cent of cases.

(*e*) Head's Area of Hyperesthesia: Head's area of cutaneous hyperesthesia in the right lower quadrant was present in 22 per cent of cases.

(*f*) Mass: Palpation revealed an abdominal mass in only 6 per cent of cases, and the incidence was correlated with the severity and stage of the disease process, it being five times as great in cases of the perforated as in those of the nonperforated type. In only 1 case was the appendix palpable through the abdominal wall, and in this case the organ was obstructed and extremely distended.

(*g*) Tenderness on Rectal Examination: Rectal examination revealed tenderness high on the right side in 65 per cent of cases.

3. *Laboratory Data.*—(*a*) Temperature: The average temperature for the entire series of cases of acute appendicitis was 100.2 F., the temperature following the severity of the process, as follows:

Acute Appendicitis	Gangrene	Localized Peritonitis	Generalized Peritonitis
99.6 F.	100.2 F.	100.8 F.	101.2 F.

There was no noticeable difference between the obstructive and the nonobstructive condition as far as fever was concerned. The average temperature in the series of delayed appendectomy was 99 F. In each type of the disease the average temperature was about 1 degree Fahrenheit higher for the pediatric age group than for the adults.

(*b*) Pulse Rate: The average pulse rate in the entire series was 96, there being a correlation between the rate and the severity of the disease. The average pulse rate in cases of obstructive appendicitis was 82, as compared with a rate of 108 in the cases of nonobstructive appendicitis. This seems to be a differential diagnostic point, but unfortunately it is apparent only in the average for a group of cases. The pulse rates were as follows:

	Acute Appendicitis	Gangrene	Localized Peritonitis	Generalized Peritonitis	Appendectomy After Interval
Minneapolis General Hospital	94	100	98	106	86
University Hospitals	96	94	96	...	88
Average	95	97	97	106	87

In each type of the disease the pulse rate averaged 10 points higher for the pediatric group than for the adult.

(*c*) Leukocyte Counts: An increased leukocyte count does not necessarily indicate infection (Downey;[107] Pepper and Farley[108]), as the average preoperative count in a series of 10 cases of noninfected strangulated hernia was 12,500 per cubic millimeter. The leukocyte count, particularly the Schilling count, in cases of appendicitis is of importance in several respects. Warnock[109] found that the Schilling count reduced the incidence of discrepancies between the preoperative diagnosis and the microscopic observations. Hellwig[110] found the total leukocyte count to be misleading because in cases of fatal appendicitis there frequently was not a high count even when peritonitis was present. He therefore opposed basing treatment on the white cell count. It is said that Ochsner always ordered a white cell count but never looked at the result until after the operation. Carlson and Wilder[111] found the Schilling count to be superior to the total leukocyte count and of more value than the temperature or the pulse rate in determining the severity of the disease process. A low leukocyte count or a shift to the left may indicate a poor prognosis. The leukocyte count in this series gave the following information:

	Appendectomy After Interval	Acute Appendicitis	Gangrene	Localized Peritonitis	Generalized Peritonitis
Average count	9,420	15,000	18,170	18,000	18,200
Under 10,000	100%	5%	5%	4%	9%
10,000 to 15,000	0	59%	24%	25%	28%
Over 15,000	0	36%	71%	71%	63%
Neutrophils					
Average number	63	79	84	86	86
Under 70	100%	15%	3%	0	5%
71 to 80	0	27%	15%	0	15%
81 to 90	0	46%	65%	79%	50%
Over 90	0	12%	17%	21%	30%

In the cases of obstructive appendicitis the total average white cell count was 16,000 per cubic millimeter as compared with 13,800 in the cases of nonobstructive appendicitis. The neutrophil counts in the two groups agreed fairly closely. In the pediatric age group the average white cell count was higher by about 2,000 cells than that in the adult group in each type of the disease.

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107. Downey, H.: Personal communication to the author.

108. Pepper, O. H. P., and Farley, D. L.: Practical Hematological Diagnosis, Philadelphia, W. B. Saunders Company, 1933.

109. Warnock, F. B.: Leucocyte Count and Histopathology in Acute Appendicitis, Am. J. Surg. **21**:47-55, 1933.

110. Hellwig, C. A.: Leucocyte Count in Acute Appendicitis, J. Kansas M. Soc. **29**:330-334, 1928.

111. Carlson, H. A., and Wilder, L.: Schilling Hemogram in Appendicitis, Arch. Surg. **30**:325-335 (Feb.) 1935.

(*d*) Urinalysis: Microscopic examination of the centrifuged specimens of urine showed red blood cells in 7 per cent of cases and leukocytes in 14 per cent. There was no significant distribution among the various types of lesions, nor was there a correlation with the presence of obstruction to the lumen of the appendix.

Wilkie [112] stated the opinion that the obstructive and the nonobstructive type of appendicitis can be differentiated clinically. He stated that obstructive appendicitis tends to cause little elevation of the pulse rate and temperature. In this investigation certain distinguishing points have been noted, but these are evident only in consideration of the group as a whole. It was not possible to diagnose obstruction of the appendix with any degree of accuracy, although the frequency of the condition makes such a diagnosis more often right than wrong.

CONCLUSIONS

1. It has been shown that in a series of 372 cases of appendicitis there was a definite organic obstruction to the lumen in 80 per cent. The obstructing mechanism was an impacted fecalith in 67 per cent of these cases. When neuromuscular and other factors are considered in the future the incidence of obstruction may be found to be much higher.

2. A study of the seasonal incidence of appendicitis over a period of eight years has shown an even distribution throughout the year. This is in accord with the idea that appendicitis is more often an obstructive phenomenon than a specific bacterial disease.

3. An inverse correlation between the history of previous attacks and the severity of the disease has been demonstrated. This is because the mild attacks tend to regress spontaneously, whereas the more severe forms usually require early operation. It is also important to note that the incidence of obstruction is much greater in cases of severe involvement.

4. It has been shown that normal excised appendixes respond to faradic stimulation for an average of three and one-half hours, whereas inflamed appendixes have such damaged musculature that an average response of only twenty-six minutes is seen. This is important in understanding why fibrosis and dysfunction may follow healing of the appendix.

5. It has been shown in a clinical experiment that distention of the appendical lumen is capable of causing a train of symptoms similar to that seen in acute appendicitis.

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112. Wilkie, D. P. D.: Observations on Mortality in Acute Appendicitis, Brit. M. J. **1**:253-255, 1931; footnote 19.

6. It has been demonstrated that culture methods and the Gram stain of tissue sections are about equally effective in determining the incidence of bacteria in the appendix. Culture methods, of course, are required for identification of the bacteria. The bacteriologic investigations presented here throw no light on the etiologic factors in appendicitis and simply indicate that a mixed flora is present.

7. The healing of appendicitis has been studied by means of special stains and the process has been observed to be one of fibrosis. It is thought possible to diagnose previous attacks by examination of microscopic sections.

8. Comparison of the histologic appearance of obstructed and that of nonobstructed appendixes has shown that the type of inflammatory process is identical in the two groups. The sole difference lies in the fact that the obstructed organs show marked thinning of the wall and distention of the lumen distal to the obstruction, whereas the wall and lumen are nearly uniform in size throughout the length of the nonobstructed appendix. These striking differences have been shown graphically by micrometry.

9. Definite organic residual signs of appendicitis have been observed in 16 per cent of cases in the entire series; that they predispose to further attacks is shown by the fact that in the cases of obstructive appendicitis there was an incidence of organic residual signs of 28 per cent as compared with the absence of such changes in the cases of nonobstructive appendicitis.

10. Chemical, roentgen and microscopic studies of appendicoliths have been made and the results recorded. It is thought that these concretions form in situ. The incidence of parasites and foreign bodies in the lumen also is mentioned.

11. From a complete analysis of the clinical cases, it does not seem possible to diagnose obstructive appendicitis with any degree of surety. The obstructive condition tends to cause more constant pain, rebound tenderness and rigidity with a lower pulse rate, but these differences are slight and are apparent only in the average for the entire group.

PRIMARY ISOLATED LYMPHOGRANULOMATOSIS (HODGKIN'S DISEASE) OF THE STOMACH

REPORT OF A CASE

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Isolated gastric Hodgkin's disease is rare. Steindl,[1] in 1924, reported the first case in the literature. Singer,[2] in 1931, collected 6 cases from the literature, added 1 case of his own and made a complete résumé of the subject. It was he who emphasized that Hodgkin's disease isolated in the stomach is an operable lesion and that with removal of the diseased tissue the prognosis is good. This idea was at variance with the accepted therapy of Hodgkin's disease, for since the time of Billroth the condition had been placed in the category of medical diseases.

REPORT OF CASE

History.—N. S., a white woman aged 63, was admitted to the John Gaston Hospital on June 15, 1937, complaining of "indigestion" of six months' duration. The indigestion was characterized by epigastric fulness and burning pain which had no relation to food intake. Loss of weight and strength had been rapid since the onset, and the digestive disturbances had been progressively more pronounced. One month prior to her admission to the hospital the patient first noticed constipation and tarry stools. At about the same time nausea and irregular vomiting began. The vomitus contained food, and occasionally "coffee grounds" were present.

In May 1937, six weeks prior to her admission to the John Gaston Hospital, the patient had been in another hospital, where a diagnosis of carcinoma of the stomach was made. Operation was advised at that time, but the patient refused to permit it and left the hospital. After two weeks, in which the vomiting had become more regular and disturbing, she came to the John Gaston Hospital desiring operation.

Except for the facts just detailed, the past history was irrelevant.

From the Department of Surgery, the College of Medicine, University of Tennessee.

The illustrations for this paper were prepared by Dr. J. L. Scianni, medical illustrator of the Department of Pathology.

1. Steindl, H.: Ueber einen Fall von Lymphogranulomatose des Magens, Arch. f. klin. Chir. **130**:110 (April) 1924.

2. Singer, H. A.: Primary Isolated Lymphogranulomatosis of the Stomach, Arch. Surg. **22**:1001 (June) 1931.

Physical Examination.—The temperature was 98 F.; the pulse rate, 80, and the blood pressure, 178 systolic and 95 diastolic. The patient was well developed but showed general signs of recent loss of weight.

The only remarkable physical findings were in the abdomen, where there was a firm, tender, freely movable mass about 7 cm. in diameter occupying the mid-

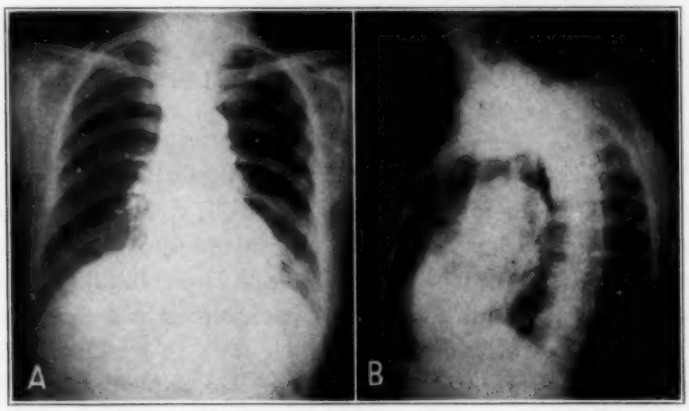

Fig. 1.—*A*, anteroposterior film of the chest, showing no mediastinal enlargement. *B*, lateral film of the chest, showing no mediastinal enlargement.

Fig. 2.—Film taken after the ingestion of barium sulfate, showing a large prepyloric deformity which was interpreted as a malignant ulcer.

epigastrium. The liver and spleen were not palpable. No abdominal masses were palpable.

Laboratory Findings.—The Wassermann and Kahn reactions were negative. The red blood cell count was 3,750,000 per cubic millimeter. The value for hemoglobin was 13 Gm. The white cell count was 11,750 per cubic millimeter, with lymphocytes 26 per cent, neutrophils 71 per cent, basophils 1 per cent and eosinophils

Fig. 3.—Operative specimen (three fourths of the stomach). It is opened along the lesser curvature. Note the large ulcer crater with its rolled, and in places inverted, edges.

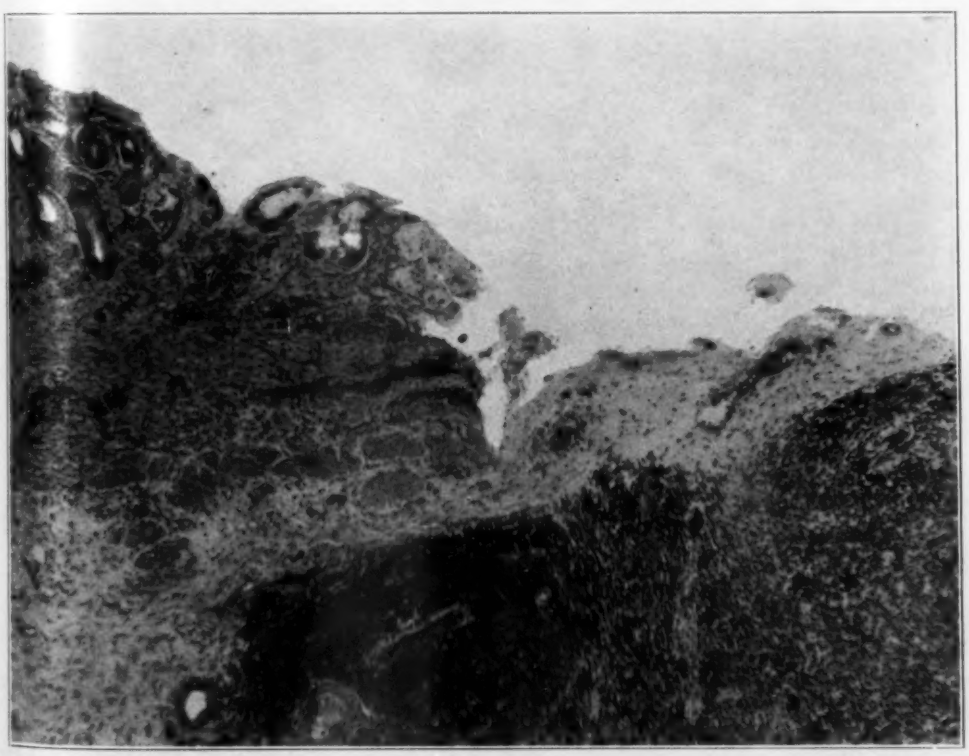

Fig. 4.—Photomicrograph (×70) showing the normal gastric glands and the submucosal lymphocytic infiltration extending well into the muscle layer and the areas of scar tissue.

2 per cent. The urine was normal. The stools and vomitus contained blood. Because of the blood in the vomitus, analysis of the gastric contents was not done.

Roentgen Examination.—Roentgenograms of the chest (fig. 1) were normal. There was no mediastinal enlargement. After administration of barium sulfate

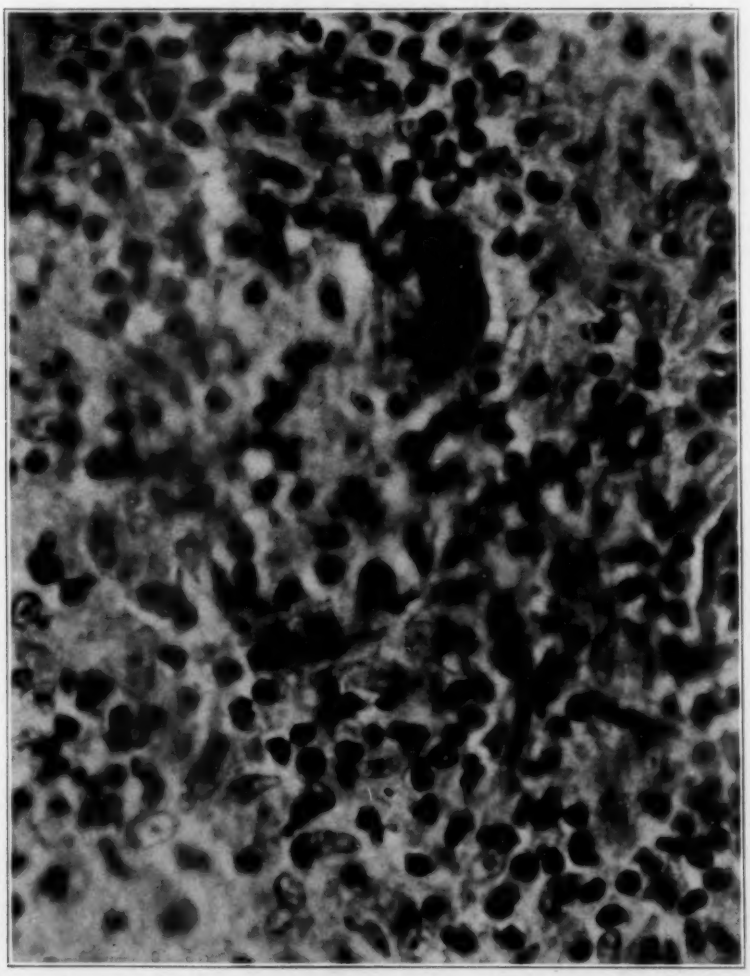

Fig. 5.—Photomicrograph (×750) showing the infiltrating lymphocytes and plasma cells. One giant cell of the Dorothy Reed type is seen also in this field.

a large prepyloric defect was seen (fig. 2). Gastric retention of the substance at six hours was 50 per cent.

The roentgenologist made a diagnosis of carcinoma of the stomach, and I agreed with him.

After four days of preparation with intravenous administration of dextrose and gastric lavage, laparotomy was performed with the patient under cyclopropane anesthesia.

There was a mass about 6 cm. in diameter occupying the prepyloric region of the stomach. The mass had the firm consistency of carcinoma and was freely movable. There was no enlargement of the neighboring lymph nodes. The liver and spleen and the mesenteric and retroperitoneal glands did not show any macroscopic or palpable pathologic condition. Believing that the growth was carcinoma of the stomach, I did a wide resection, removing three fourths of the stomach and 5 cm. of the duodenum. Continuity of the intestinal canal was effected by a posterior, end to side gastrojejunostomy.

The patient died on the fourth postoperative day, of bronchopneumonia. Postmortem examination was not permitted.

Pathologic Examination.—Macroscopic: The specimen consisted of a portion of the stomach and the adjoining part of the duodenum. When the stomach was opened there was seen an irregularly oval ulceration measuring 9.5 by 5.5 cm. in its greatest diameters. It was immediately prepyloric (fig. 3). The edges of the ulcer were rolled and in certain areas were inverted. The wall of the crater sloped irregularly to a depth of 1.5 cm. The face of the ulcerated area was firm, granular and mottled gray to yellow. The wall of the stomach varied in thickness up to 1.5 cm. The muscular layer was thickened. A few omental tags were adherent to the serosal surface, but there was no evidence of perforation.

Microscopic: The mucosa showed moderate infiltration with lymphocytes and plasma cells. There was an occasional eosinophil. The glands were essentially normal. There was an ulceration which extended into the muscularis, the surface of which was necrotic and infiltrated with polymorphonuclear leukocytes (fig. 4). The submucosa and muscularis were heavily infiltrated with lymphocytes and plasma cells. The muscle bundles in many places were indistinguishable. A moderate number of eosinophils were scattered about, and Dorothy Reed cells were seen (fig. 5). Lymphoid cells showed a moderate number of mitoses.

Pathologic Diagnosis: A diagnosis of lymphogranulomatosis of the stomach with ulceration was made.

COMMENT

Of the 7 patients in the cases discussed by Singer,[2] 2 died incidentally to the operation. The remaining 5 patients had survived without apparent recurrence of disease for periods varying from a few months to four years. From the survival of these 5 patients Singer concluded that the prognosis is good in cases of isolated lymphogranulomatosis of the stomach after surgical removal.

In 1935, Comando [3] reported a case of Hodgkin's disease of the stomach after failing to find a case in the literature since Singer's résumé. Comando's patient recovered promptly from a subtotal gastrectomy and was well five years later. Comando agreed with Singer that the prognosis is good if resection is done.

Since Comando's report I have found 1 additional case, reported by Imai.[4] This case is interesting and demands close consideration.

3. Comando, H. N.: Primary Isolated Lymphogranulomatosis of the Stomach, Arch. Surg. **30**:228 (Feb.) 1935.

4. Imai, M.: Primary Lymphogranulomatosis of the Stomach, J. Orient. Med. **23**:113 (Dec.) 1935.

The patient was a 66 year old man who was operated on for gastric carcinoma. A lesion was found confined to the stomach, and careful exploration revealed all the other abdominal viscera to be normal. A subtotal gastrectomy was done. Microscopic examination of the resected stomach showed the typical histologic picture of Hodgkin's disease. The patient died two years later, and at postmortem examination a mass was found in the transverse colon, at the hepatic flexure. Microscopically this mass was typical of Hodgkin's disease and was identical with the gastric lesion removed two years previously.

This case suggests the possibility that lymphogranulomatosis is a progressive disease of the mesenchymal tissue, and a guarded prognosis must be made even after all apparently diseased tissue has been removed surgically.

All authors of reported cases have stressed the possible presence of microscopic disease unrecognized at the time of operation. That possibility was surely present in the case reported in this paper and is further emphasized by a case reported by Kamniker and Kratochwil.[5] They operated for what appeared to be isolated Hodgkin's disease of the stomach, only to find at postmortem examination that there were multiple microscopic lesions in the liver, spleen and bone marrow.

There is nothing characteristic in the symptoms of isolated lymphogranulomatosis of the stomach. The condition in all cases reported has been diagnosed clinically either as carcinoma or as benign ulcer. Apparently the disease is confined to no age group, as it has been seen from the third to the seventh decade. When the condition is isolated in the stomach, the febrile state associated with the general forms of the disease is not present. Operation after a mistaken diagnosis will continue to be done until more facts are learned of the disease than are now known.

SUMMARY

A case of lymphogranulomatosis (Hodgkin's disease) isolated in the stomach is reported.

A brief résumé of the literature is made.

The prognosis of lymphogranulomatosis of the stomach should be guarded even after surgical removal of the diseased tissue.

Diagnosis of this condition is practically impossible to make before microscopic examination of the lesion is done.

Medical Arts Building.

5. Kamniker, K., and Kratochwil, K.: Zur Lymphogranulomatose des Magens, Deutsche Ztschr. f. Chir. **247**:383, 1936.

CIRCULATION DURING SPINAL ANESTHESIA

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AND
HARRY KOSTER, M.D.
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There is no adequate explanation for the marked fall in blood pressure which accompanies spinal anesthesia. In order to explain the mechanism by which this hypotension is developed, it would be necessary to know in detail all the changes which occur in the circulatory system. Thus far studies have shown conclusively that:

1. Systolic and diastolic blood pressures usually fall to a variable degree.[1]

2. Sympathomimetic drugs usually either prevent the fall or produce a subsequent rise of blood pressure.[2]

3. There is a rise in cutaneous temperature of the lower extremities.[3]

Beside these definite findings, Webb, Scheinfeld and Colin [4] reported that there was no significant variation in circulation time during spinal anesthesia in the 6 patients they studied.

We investigated the effect of spinal anesthesia on blood volume, venous pressure, circulation time, viscosity of the blood and cardiac output and its related functions.

From the Richard Morton Koster Research Laboratory, the Crown Heights Hospital.

1. Bradshaw, H. H.: The Fall in Blood Pressure During Spinal Anesthesia, Ann. Surg. **104**:41, 1936.

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METHOD

The subjects of these studies were surgical patients operated on for a variety of conditions. Control studies were made under similar conditions on patients, convalescents and volunteers to determine the effect of intervals without spinal anesthesia.

In each experiment the changes in circulatory phenomena were determined by observations made immediately before and during spinal anesthesia. The anesthetic was administered through a spinal puncture between the second and the third lumbar vertebra after procaine hydrochloride had been thoroughly mixed with 4 cc. of cerebrospinal fluid.[5] No sympathomimetic or other medication was used to prevent a fall in blood pressure. The dose of procaine hydrochloride was 150 mg. except as otherwise indicated in the tables.

Blood volume was determined by Smith's [6] modification of the brilliant vital red method, which permitted repetition within a short time.

The venous pressure was measured by the direct method [7] at the time of one of the venous punctures in 7 patients of the previous group. A graduated L tube was attached to a 16 gage needle which had been inserted in the antecubital vein. The point of the needle was adjusted to a fixed portion of the patient's torso, which was marked with tincture of iodine. This procedure was followed in order to avoid difficulty in leveling two widely separated points, the arm and the base of the sternum, as is the usual practice. Our data on venous pressure are therefore relative.

The circulation time from the antecubital vein to the medulla was measured by the sodium cyanide method of Robb and Weiss.[8]

The cardiac output and its related functions were determined by the acetylene method of Grollman.[9] The two determinations were completed within one hour under similar conditions. The control subjects were not studied under basal conditions, since we were interested only in checking the effect of repetition of the experiment after a short interval. All of the observations on cardiac output, oxygen consumption and pulse rate were completed before the start of the operation.

It will be seen from the tables that in no instance were all the data obtained from the same patient, as this was found to be impracticable. All the measurements of

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5. Koster, H.: Spinal Anesthesia, with Special Reference to Its Use in Surgery of the Head, Neck and Thorax, Am. J. Surg. **5**:554, 1928.

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7. Moritz, F., and von Tabora, D.: Ueber ein Methode, beim Menschen den Druck in oberflächlichen Venen exakt zu bestimmen, Deutsches Arch. f. klin. Med. **98**:475, 1910.

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venous pressure were on patients in whom blood volume had been studied, and six of the ten measurements of cardiac output, oxygen consumption and pulse rate were made together with estimation of the circulation time.

RESULTS

The data are shown in the tables and summarized in table 3. The significance of the changes was calculated according to the method of Fisher.[10]

TABLE 1.—*Changes of Blood Volume and Venous Pressure During Spinal Anesthesia*

	Control Observations					
	Blood Volume, Liters			Venous Pressure, Cm.		
	Observation		Difference,	Observation		Difference
Experiment	I	II	%	I	II	
9	5.63	5.78	+ 2.6	6.8	7.2	+0.4
10	5.88	5.23	−11.7	11.4	10.5	−0.9
11	5.34	5.57	+ 4.2	9.5	8.6	−0.9
12	5.58	5.98	+ 6.9	11.8	12.2	+0.4
14	4.65	4.68	+ 0.6	12.8	11.2	−1.6
16	3.66	3.64	− 0.5			
17	6.04	6.12	+ 1.3	17.4	16.8	−0.6
18	3.70	3.22	−13.8	23.0	24.2	+1.2
Mean difference.....			−1.3 ± 1.46			−0.3 ± 0.23

	Experiments								
	Blood Volume, Liters			Venous Pressure, Cm.			Blood Pressure, Mm.		
Experiment	Before	After	Change, %	Before	After	Change	Before	After	Change
13	5.27	4.64	−11.9	20.2	14.8	−5.4	110	29	−81
1	5.98	4.46	−25.2	9.8	5.4	−4.4	95	45	−50
7	5.24	3.71	−29.1	5.2	4.2	−1.0	128	60	−68
5	7.05	5.75	−18.5	5.8	4.0	−1.8	85	60	−20
4	7.74	7.10	− 8.4	...	...	.....	78	60	−18
2	5.16	4.95	− 4.0	...	...	.....	108	70	−38
6	5.96	5.94	− 0.3	8.0	6.8	−1.2	80	68	−12
3	4.17	4.28	+ 2.6	7.6	11.2	+3.6	98	60	−33
15	4.41	4.55	+ 3.2	...	....	...	101	68	−34
19	3.84	3.97	+ 3.4	16.4	15.4	−1.0	108	70	−38
8	3.53	3.73	+ 5.7	....	....	.....	115	88	−27
20	4.05	4.56	+12.6	20.0	17.0	−3.0	92	65	−27
17	6.12	7.08	+15.7	16.8	14.2	−2.6	99	73	−26
Mean change.....			−4.17 ± 2.5			−1.9 ± 0.59			

SUMMARY

The average of systolic and diastolic blood pressures fell in 59 of 60 cases. This is in agreement with previous reports of the fall in blood pressure during spinal anesthesia.

10. Fisher, R. A.: Statistical Methods for Research Workers, ed. 6, Edinburgh, Oliver & Boyd, 1936.

TABLE 2.—*Changes in Viscosity of the Blood*

Control Observations				Experiments						
	Relative Viscosity, Sec.				Relative Viscosity, Sec.			Blood Pressure, Mm.		
	Observation									
Experiment	I	II	Difference	Experiment	Before	After	Change	Before	After	Change
70	8.0	8.0	0.0	70	8.0	7.9	—0.1	118	65	—53
71	7.6	7.6	0.0	71	7.6	7.5	—0.1	110	80	—30
72	7.6	7.6	0.0	72	7.6	7.6	0	95	60	—35
73	7.4	7.4	0.0	73	7.4	7.4	0	75	23	—52
74	7.4	7.6	+0.2	74	7.5	7.7	+0.2	120	70	—50
75	7.0	7.2	+0.2	75	7.1	6.7	—0.4	115	45	—70
76	6.8	7.0	+0.2	76	6.9	6.8	—0.1	100	68	—32
77	7.2	7.4	+0.2	77	7.3	7.2	—0.1	105	80	—25
78	7.8	7.8	0.0	78	7.8	7.7	—0.1	103	70	—33
79	7.2	7.4	+0.2	79	7.3	7.3	0	95	72	—23
80	8.0	7.8	—0.2	80	7.9	7.9	0	115	102	—13
81	7.4	7.6	+0.2	81	7.5	7.6	+0.1	110	97	—13
Mean difference..... +0.08 ± 0.08				Mean change..... —0.05 ± 0.04						

TABLE 3.—*Changes in Circulation Time*

Control Observations				Experiments						
	Circulation Time, Sec.				Circulation Time, Sec.			Blood Pressure, Mm.		
	Observation									
Experiment	I	II	Difference	Experiment	Before	After	Change	Before	After	Change
21	16.5	17.0	+0.5	21	18.2	25.5	+ 7.3	117	75	—32
22	11.2	12.8	+1.6	22	12.0	25.0	+13.0	120	75	—45
23	9.5	9.6	+0.1	23	9.6	22.4	+12.8	105	75	—30
24	13.2	15.0	+1.8	24	14.1	28.2	+14.1	120	65	—55
25	12.2	13.4	+1.2	25	12.8	20.6	+ 7.8	94	92	— 2
27	11.2	13.0	+1.8	26	22.0	23.4	+ 1.4	105	75	—30
28	13.5	12.0	—1.5	27	12.1	44.3	+32.2	134	65	—69
29	20.0	21.0	+1.0	28*	12.8	28.0	+15.2	103	68	—35
31	12.0	11.4	—0.6	29	20.5	30.2	+ 9.7	123	70	—53
32	15.0	14.0	—1.0	30*	14.0	24.0	+10.0	108	75	—33
33	12.4	15.0	+2.6	31	11.7	20.0	+ 8.3	100	75	—25
34	15.0	19.8	+4.8	32	14.5	24.1	+ 9.6	105	65	—40
35	7.0	6.8	—0.2	33	13.7	21.4	+ 7.7	95	75	—20
37	9.0	9.0	0.0	34*	17.4	18.0	+ 0.6	70	55	—15
38	10.4	10.6	+0.2	35†	6.9	11.0	+ 4.1	95	100	+ 5
39	11.0	15.0	+4.0	36*	26.0	24.6	— 1.4	118	90	—28
40	13.2	15.8	+2.6	37*	9.0	21.0	+12.0	90	83	— 7
41	10.0	12.0	+2.0	38*	10.5	49.0	+38.5	108	65	—43
42	15.0	15.0	0.0	39*	13.0	15.4	+ 2.4	98	90	— 8
				40*	14.5	25.0	+10.5	95	70	—25
Mean difference.....+1.2 ± 0.25				41	11.0	15.0	+ 4.0	88	70	—18
				42	15.0	21.0	+ 6.0	95	65	—30
				43	14.0	28.0	+14.0	125	55	—70
				47	11.4	25.2	+13.8	93	58	—35
				48A†	18.0	20.2	+ 2.2	120	85	—35
				49†	13.4	24.0	+10.6	120	113	— 7
				50	12.0	21.6	+ 9.6	110	68	—42
				51	20.0	26.0	+ 6.0	88	85	— 3
				53	26.0	27.2	+ 1.2	85	65	—20
				54	15.0	22.4	+ 7.4	90	63	—27
				55	11.6	24.0	+12.4	98	80	—18
				Mean change.....+9.7 ± 0.98						

* 300 mg. procaine used for anesthesia.
† 100 mg. procaine used for anesthesia.

The pulse rate showed an average decrease of 16 beats, or 19 per cent. There was no significant change in the viscosity of the blood or in the blood volume (tables 1 and 2). The mean fall in venous pressure

TABLE 4.—*Changes in Cardiac Output and Related Functions*

Experiment	Control Observations: Oxygen Consumption, Cc./Min. — Observation I	Observation II	Difference, %	Cardiac Output, Liters/Min. — Observation I	Observation II	Difference, %	Cardiac Index, Liters
44	232	232	0.0	4.35	4.57	+ 4.9	2.30
45	248	248	0.0	4.28	4.47	+ 4.3	2.18
46	213	213	0.0	4.77	5.12	+ 7.1	2.74
50	257	227	−12.4	3.53	4.00	+12.5	2.08
56	193	193	0.0	4.96	4.31	−14.3	2.92
57	295	270	−8.9	5.18	5.61	+ 8.0	2.85
61	256	237	−7.9	4.52	4.35	− 3.8	2.31
62	201	206	+2.5	3.60	3.42	− 5.1	1.98
Mean difference			−3.3 ± 1.25			+1.7 ± 1.93	

Experiment	Experiments: Oxygen Consumption, Cc./Min. — Before	After	Change %	Cardiac Output, Liters/Min. — Before	After	Change	Pulse per Min. — Before	After	Change	Blood Pressure, Mm. — Before	After	Change	Cardiac Index, Liters
47	205	215	+ 4.8	4.81	1.82	−62	86	64	−22	92	62	−30	2.50
48*	273	242	−12.1	3.17	1.88	−41	74	80	+ 6	92	64	−28	1.82
48A*	247	242	− 2.0	3.12	2.28	−27	84	72	−12	120	85	−35	1.72
49*	376	348	− 7.8	4.96	4.73	− 5	96	84	−12	120	112	− 8	2.67
53	233	242	+ 3.8	3.73	3.12	−16	68	48	−20	85	65	−20	2.14
54	169	170	+ 0.5	4.59	2.64	−21	84	60	−24	90	62	−28	3.06
55	184	184	0	4.39	1.87	−55	96	60	−36	98	80	−18	2.58
58	171	182	+ 6.2	3.66	2.45	−33	90	90	0	92	82	−10	2.46
59	219	209	− 4.7	4.74	3.49	−26	82	76	− 6	98	85	−13	3.00
60	239	229	− 4.3	6.08	3.78	−37	96	72	−37	142	75	−67	3.24
Mean change			−1.56 ± 1.16			−32.3 ± 3.48			−16 ± 4.4				

* 100 mg. procaine hydrochloride used for anesthesia.

TABLE 5.—*Statistical Significance of the Difference Between the Deviations of the Control and the Experimental Observations*

	Mean of the Differences Between Control Observations	Mean of the Changes After Spinal Anesthesia	Difference ± Probable Error of the Difference	Probability That Difference is Not Due to Sampling, %
Viscosity	+0.08 ± 0.08	−0.05 ± 0.028	−0.13 ± 0.09	68
Blood volume	−1.3 ± 1.77 %	−4.17 ± 2.6 %	−2.87 ± 2.9 %	49
Venous pressure	−0.3 ± 0.18 cm.	−1.9 ± 0.50 cm.	−1.6 ± 0.64 cm.	91
Circulation time	+1.2 ± 0.25 sec.	+9.7 ± 0.98 sec.	8.5 ± 1.01 sec.	100
Cardiac output	+1.7 ± 1.63 %	−32.3 ± 3.68 %	−34 ± 3.98 %	100
Oxygen consumption	−3.3 ± 1.32 %	−1.56 ± 1.24 %	1.74 ± 1.7 %	50

of 1.9 cm. of saline solution has about a 90 per cent chance of being significant according to the method of calculation used in obtaining the data presented in table 5. However, the occurrence in 8 of

9 anesthetized patients of the same direction of change in venous pressure (a fall) would be found only 96 per cent of the time. The data indicate, therefore, that antecubital venous pressure probably falls significantly but by an amount which has not been precisely estimated.

The circulation time from arm to brain increased 60 per cent after spinal anesthesia (table 3).

The cardiac output fell 32.3 per cent (table 4). There was no significant associated change in oxygen consumption.

CONCLUSION

A significant fall in cardiac output, pulse rate and venous pressure and an increase in circulation time from arm to brain are associated with spinal anesthesia in man.

THYROTOXICOSIS WITH MALIGNANT NEOPLASMS OF THE THYROID GLAND

A CLINICOPATHOLOGIC STUDY

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The incidence of malignant disease of the thyroid gland is low. Various observers have shown that it does not rise much above 1 per cent for all autopsies. Wilson [1] estimated its occurrence at 0.11 per cent, Hinterstoisser [2] at 0.27 per cent and Wegelin [3] at 1.04 per cent. In spite of considerable study (von Eiselsberg;[4] Langhans;[5] Kocher;[6] Trotter;[7] Klose and Hellwig;[8] Rogers;[9] Meleney;[10] Carrel;[11] Speese and Brown;[12] Bloodgood;[13] Balfour;[14] Simpson;[15] Wilson;[1] Ewing;[16]

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Graham [17]), the diagnosis of malignant disease of the gland, both clinical and histologic, remains difficult. The disease in at least one third of the cases is diagnosed incorrectly prior to operation, and it is probable that the condition frequently is unrecognized even after operative exposure. Hitherto the pathologic study of malignant neoplasms of the thyroid gland has been conducted from the morphologic point of view. It is possible that a study of these growths from the standpoint of function may lead to some simplification of the problems involved. Accordingly, this study has been undertaken with the object of focusing attention on the types of malignant thyroid tumor accompanying thyrotoxicosis. Furthermore, since this thyrotoxicosis appears to be truly thyrogenic, such an investigation may help to throw light on the problem of thyroid function in general.

FUNCTIONING OF MALIGNANT THYROID NEOPLASMS

The possibility of function occurring in malignant disease of the thyroid gland probably had been thought of many years before the time of von Eiselsberg. However, no observation of importance had been made until von Eiselsberg's case [4] was reported in the literature. In 1881 Tillaux [18] reported a case of sarcoma of the thyroid gland in which symptoms of thyrotoxicosis were present. This is the only case of thyrotoxicosis with sarcoma of the thyroid which has been verified. Many other writers have reported the occurrence of sarcomas of the gland with toxic symptoms, but their reports have not been substantiated. After this, a London physician, Dr. G. Gulliver,[19] read before the Pathological Society of London the report of a case of malignant disease of the thyroid gland in which myxedema had occurred. Two schools of thought now sprang up, the German and the French. The German school, founded by von Eiselsberg, was filled, up to the close of the nineteenth century, with such physicians as Harmer,[20] von Rehn,[21] Mosler,[22] Hürthle [23] and Lücke.[24] Little was done by the French school

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by the end of the nineteenth century, for Tillaux [18] was followed only by Bertrand,[25] who wrote in 1896 a thesis on acute and latent cancer of the thyroid.

In the first decade of the twentieth century an outburst of activity took place in France, and the writings of Faisant,[26] Bérard,[27] Carrel,[11] Hébert,[28] Bérard and Alamartine,[29] Broeckaert [30] and Delore and Alamartine [31] found a place in the literature. Meanwhile, in Germany, Stejskal,[32] Hirschfeld,[33] Caro,[34] Löwy,[35] Lobenhoffer [36] and Gierke [37] were active. The work of Marine and Johnson [38] exerted a profound influence on the German school but practically none on the French. A scientific study was now initiated in Germany of the problem of function in malignant neoplasms of the thyroid gland (Mori;[39] Ewald;[40] Lyon;[41]

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Meyer-Hürlimann and Oswald;[42] Erdheim;[43] Branovacky;[44] Lublin;[45] Hoffmann;[46] Winkler;[47] Stange,[48] and others). In France, Pallasse and de Lambert[49] have written on this subject; in English speaking countries, Eisen,[50] Simpson,[15] Kolodny[51] and Crile,[52] and in Italy, Pescatori.[53]

The theory held by the German school is that the thyrotoxic symptoms are due not to functioning of the malignant growth itself but to stimulation of the thyroid tissue surrounding the primary growth. That held by the French school, on the other hand, is that the toxic symptoms are the result of actual function of the malignant cells. Of course, it need scarcely be stated that not all adherents of each school take the central point of view of that school, for many favor some modification of it.

That thyrotoxicosis does accompany malignant neoplasms of the thyroid gland is generally acknowledged. Many writers have described cases of primary tumor of the gland with toxic symptoms (Löwy;[35]

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Ehrhardt;[54] Boeckel;[55] Haemig;[56] Harmer;[20] Cornil;[57] Kocher;[6] Hébert;[28] Clunet;[58] Tillaux;[18] Lyon;[41] Broeckaert;[30] Meyer-Hürlimann and Oswald;[42] Klose and Hellwig,[8] and others). In view of these reports extending over half a century, the existence of thyrotoxicosis with malignant neoplasms of the thyroid gland cannot be doubted. The criteria used by various workers in their determination of the thyrotoxic state have varied greatly.

How are the thyrotoxic symptoms produced? What is the mechanism of their production in primary and secondary malignant disease of the thyroid gland?

1. The toxic symptoms associated with primary tumors may be due to:
   - (*a*) Functioning of the malignant neoplastic tissue
   - (*b*) Basedowification of the thyroid tissue surrounding the malignant mass by
     - (1) Toxic substances from the growth
     - (2) Mechanical irritation of the neoplasm
   - (*c*) Absorption or hyperabsorption of normal colloid which has been set free from acini invaded by the neoplasm
   - (*d*) Absorption or hyperabsorption of altered colloid or colloid from abnormal acini
2. The toxic symptoms associated with secondary tumors may be due to any of the factors, *b*, *c* or *d*, active in the case of primary tumors
3. Thyrotoxicosis may occur from thyroid metastases (Löwy;[35] Stejskal[32])
4. Thyrotoxicosis may occur from thyroid ectopias (Kovács;[59] Moench[60])

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TRUE AND FALSE THYROTOXICOSIS

In distinguishing true from false thyrotoxicosis it is dangerous to stress the importance of a single sign or symptom. For instance, it is common to evaluate too highly the basal metabolic rate, in spite of contradictory clinical evidence. Hypermetabolism per se is not thyrotoxicosis. In all forms of malignant disease the metabolic rate is usually raised as high as +10 to +40 per cent (Grafe;[61] Du Bois;[62] Strieck and Mulholland;[63] Kraus;[64] Wallersteiner;[65] Magnus-Levy[66]). Heindl and Trauner[67] in an examination of material from the von Eiselsberg clinic established that in patients with cancer the basal metabolic rate may be raised to +40 per cent.

ANALYSIS OF PRESENT SERIES

The present study concerns a group of 50 cases, in all of which operation was performed and tissue was removed from the thyroid gland. Malignant disease of the gland was suspected or definitely diagnosed prior to operation in about one third of these cases. In every case a microscopic diagnosis of malignant neoplasm of the thyroid gland was made.

Sex Incidence.—Of the 50 patients, 40 were females and 10 males—a ratio of 4 to 1.

Age Incidence.—A study of the age incidence revealed several interesting facts. The average age for the entire group was 47 years, and there was a gross variation from a minimum of 7 to a maximum of 72 years. A subdivision of the entire series into two groups, those with and those without thyrotoxicosis, was made. In chart 1 is illustrated the relative age incidence in each group. The maximum age incidence of the nontoxic group lies, like that of the total series, between 40 and 50 years. Thyrotoxicosis, on the other hand, reached its peak in patients between 50 and 60 years of age. It is difficult at present to explain this variation in age incidence between the different groups.

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62. Du Bois, E. F.: Basal Metabolism in Health and Disease, Philadelphia, Lea & Febiger, 1923.

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Incidence of Thyrotoxicosis.—Of the 50 patients, 14 showed cleancut evidences of thyrotoxicosis, an incidence of 28 per cent. Other observers (e. g., Simpson [15]) have found a higher incidence of thyrotoxic symptoms in such cases, placing it in the neighborhood of 50 per cent. This may be explainable by the wide variation in criteria used in the diagnosis of thyrotoxicosis by many investigators. Of the 10 male patients in this series not one revealed any thyrotoxic symptoms.

Duration of Symptoms.—An unsuccessful attempt was made to determine whether any relation existed between the duration of the thyrotoxic symptoms and the metabolic rate. It was noted, however, that the patient with the shortest duration of thyrotoxicosis (one month) had a

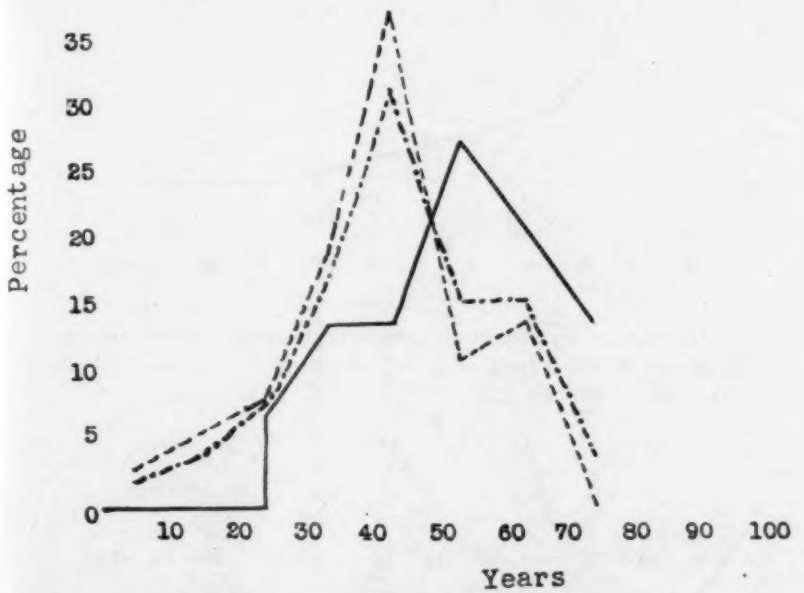

Chart 1.—Age incidence. The figures at the bottom of the chart represent the age range; those at the left, the percentage. The unbroken line represents the thyrotoxic group; the broken line, the nonthyrotoxic group; the line composed of dots and dashes, the total incidence.

metabolic rate of +63 per cent, the highest in this group. The duration of thyrotoxicosis varied from one month to twelve years (chart 2). It seems unlikely that a malignant neoplasm could have existed in the thyroid gland for twelve years. One must assume, therefore, that the neoplasm developed in a hyperfunctioning gland. In chart 3 is shown the relative duration of goiter of the toxic and the nontoxic type. Goiter of less than two years' duration more frequently was toxic (33 per cent) than nontoxic (19 per cent). In 50 per cent of cases of thyrotoxicosis it had been present for one year or less, while in more than 70 per cent its duration did not exceed two years.

Metabolism.—Metabolic studies were made of both the toxic and the nontoxic group. In the toxic group the rate of metabolism varied from + 10 to + 75 per cent, in the majority being between + 10 and + 40 per

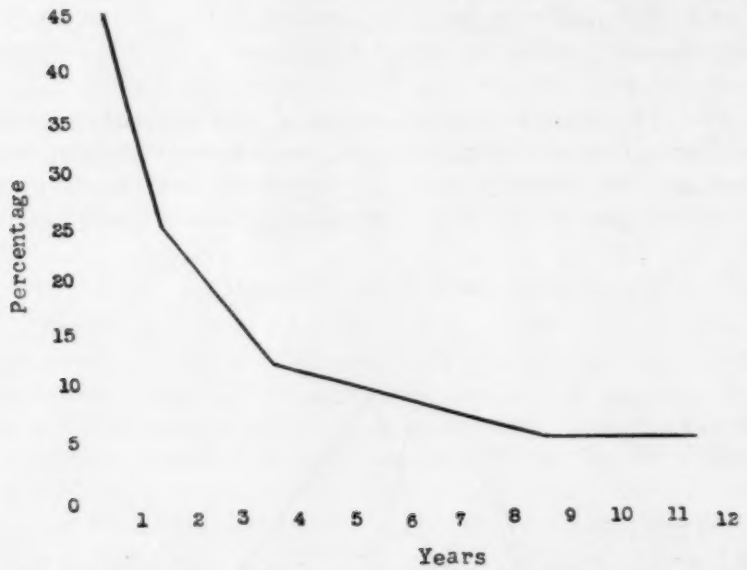

Chart 2.—Duration of thyrotoxicosis in cases of malignant tumor of the thyroid gland. The figures at the bottom of the chart represent the duration in years; those at the left, the percentage.

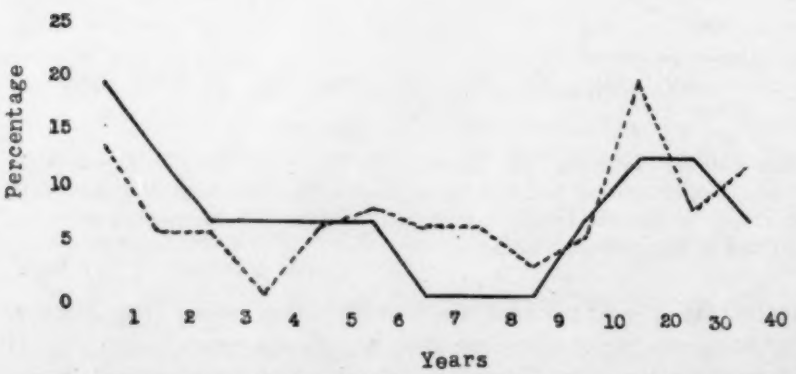

Chart 3.—Duration of goiter. The figures at the bottom of the chart represent the duration in years; those at the left, the percentage. The unbroken line represents thyrotoxic goiter; the broken line, nonthyrotoxic goiter.

cent. In the nontoxic group the metabolic rates lay between —25 and +45 per cent, the large majority being between —5 and +10 per cent. It will be noticed from chart 4 that a number of patients in the

nontoxic group revealed elevated metabolic rates. In these no signs of thyrotoxicosis were present; their condition was classified under a subdivision designated by the term pseudothyrotoxicosis.

Pathologic Picture.—In most instances the type of neoplasm was epithelial. The following forms were encountered in this series:

1. Adenocarcinoma
2. Medullary carcinoma
3. Papillary adenocarcinoma
4. Squamous cell epithelioma
5. Fibrosarcoma

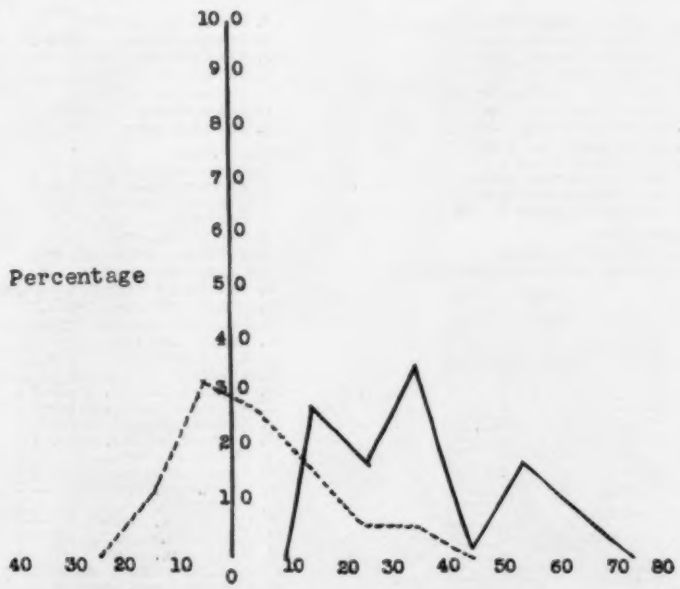

Chart 4.—Metabolism in cases of malignant neoplasm of the thyroid gland. The figures at the bottom of the chart represent the basal metabolic rate. The unbroken line represents toxic neoplasms; the broken line, nontoxic neoplasms.

In the entire series, only 2 tumors were squamous epitheliomas and 1 was a fibrosarcoma. The neoplasms were graded according to Broders' classification. In the thyrotoxic group 75 per cent were graded 1 and 2, and 22 per cent, 3 and 4, only 7 per cent being graded 4. In the nonthyrotoxic group 52 per cent were graded 1 and 2 and 48 per cent were graded 3 and 4, 25 per cent being graded 4. This is in distinct contrast to the low percentage of grade 4 tumors seen in the thyrotoxic group. A cytologic study of the neoplasms in both groups indicated that the type of cell present was the common thyroid cell. In a few instances the neoplasms were found to consist of large cells with clear cytoplasm

and vesicular nuclei. This type of growth probably corresponds to the Hürthle type of carcinoma. In many of the neoplasms gross hemorrhages could be found. From table 1 it can be seen that hemorrhage apparently is more frequent with toxic than with nontoxic goiter. It is not possible as yet to state the exact reason for this. A search was made in the thyroid glands, both in the neoplasm and in the surrounding thyroid tissue, for evidences of regenerative hyperplasia. This type of

TABLE 1.—*Thyrotoxicosis: Relation to Intraneoplastic Hemorrhage*

Thyrotoxic group (14 cases)	Nonthyrotoxic group (36 cases)
Hemorrhage	Hemorrhage
1. Papillary adenocarcinoma, grade 1	1. Carcinoma, grade 4
2. Adenocarcinoma, grade 2	2. Adenocarcinoma, grade 2
3. Adenocarcinoma, grade 2	3. Papillary adenocarcinoma, grade 1
4. Adenocarcinoma, grade 3	4. Squamous cell epithelioma, grade 4
5. Papillary adenocarcinoma, grade 1	5. Carcinoma, grade 4
6. Adenocarcinoma, grade 2	6. Adenocarcinoma, grade 2
7. Adenocarcinoma, grade 1	7. Papillary adenocarcinoma, grade 1
8. Adenocarcinoma, grade 2	No hemorrhage
9. Carcinoma, grade 3	1. Carcinoma, grade 4
10. Adenocarcinoma, grade 2	2. Adenocarcinoma, grade 2
11. Adenocarcinoma, grade 2	3. Papillary adenocarcinoma, grade 1
12. Carcinoma, grade 2	4. Carcinoma, grade 2
No hemorrhage	5. Carcinoma, grade 2
1. Carcinoma, grade 4	6. Adenocarcinoma, grade 2
2. Papillary adenocarcinoma, grade 1	7. Carcinoma, grade 4
	8. Papillary adenocarcinoma, grade 1
	9. Adenocarcinoma, grade 2
	10. Papillary adenocarcinoma, grade 2
	11. Carcinoma, grade 3
	12. Adenocarcinoma, grade 3
	13. Papillary adenocarcinoma, grade 1
	14. Adenocarcinoma, grade 3
	15. Adenocarcinoma, grade 1
	16. Adenocarcinoma, grade 1
	17. Adenocarcinoma, grade 2
	18. Carcinoma, grade 4
	19. Adenocarcinoma, grade 4
	20. Carcinoma, grade 3
	21. Carcinoma, grade 3
	22. Carcinoma, grade 2
	23. Adenocarcinoma, grade 3
	24. Carcinoma, grade 4
	25. Adenocarcinoma, grade 1
	26. Fibrosarcoma, grade 3
	27. Squamous cell epithelioma, grade 3
	28. Adenocarcinoma, grade 1
	29. Carcinoma, grade 1

hyperplasia was found in varying degrees from a few scattered regenerative hyperplastic cells to extensive areas of regenerative hyperplasia. Regenerative hyperplasia was more common and more extensive in neoplasms of low grade malignancy than in the more malignant growths. In addition, it occurred more frequently in papilliferous than in nonpapilliferous neoplasms. Moreover, it appeared to be less frequent with thyrotoxicosis. Whether or not there exists any true relation between the presence or absence of regenerative hyperplasia and the presence or absence of thyrotoxicosis cannot be definitely stated. However, it is my impression that such a relation does not exist.

Relation of Differentiation of Growth to Thyrotoxicosis.—In every instance in which thyrotoxicosis was present structural evidences of function were found either in the neoplasm or in the surrounding thyroid tissue. In some neoplasms the malignant acini were lined with tall columnar cells and filled with pale-staining vacuolated material resembling colloid. In other instances signs of hyperfunction were found not in the growth itself but in the surrounding tissue. This was particularly true when the neoplasm was more or less differentiated. Chart 5 illustrates the fact that

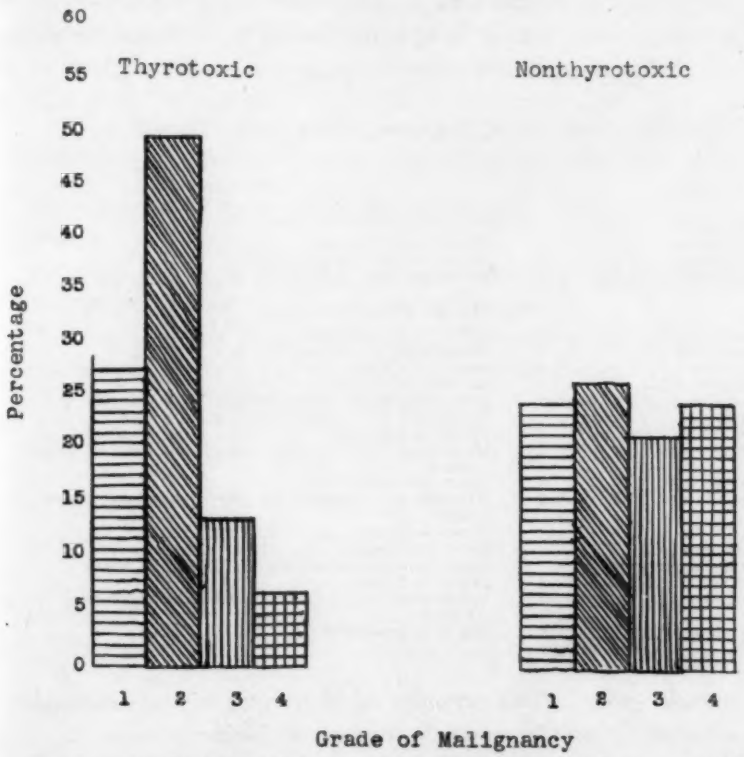

Chart 5.—Thyrotoxicosis in relation to the grade of malignancy of the tumor. The figures at the bottom of the chart represent the grade of malignancy; those at the left, the percentage.

in the majority of cases of thyrotoxicosis the neoplasms are of a low grade of malignancy. These data may be interpreted in two ways. There is the possibility that well differentiated neoplasms are more capable of functioning and therefore of producing the symptoms of thyrotoxicosis. On the other hand, it is possible that a neoplasm of low malignancy by its slower growth is more capable of producing a specific basedowifying effect on the surrounding thyroid epithelium. In either case the

constitutional predisposition of the thyroid gland to basedowification may be the determining factor (Klose and Hellwig;[8] Warthin[68]).

PROGNOSIS OF MALIGNANT NEOPLASMS OF THE THYROID GLAND IN RELATION TO THYROTOXICOSIS

An examination of the rate of survival in the present series of malignant neoplasms of the thyroid gland reveals an interesting fact. Over a period of five years death from tumor occurred in 21.4 per cent of the thyrotoxic group in contrast to a death rate of 44.4 per cent in the nonthyrotoxic group. This is in agreement with the fact that the general grade of malignancy in the thyrotoxic group is lower than in the nonthyrotoxic group. The presence of thyrotoxicosis accompanying a malignant thyroid neoplasm would suggest a distinctly more favorable prognosis over a five year postoperative period (table 2).

TABLE 2.—*Prognosis of Malignant Disease of the Thyroid Gland*

Neoplasm	Grade	Comment
		Thyrotoxic Group (14 Cases)
Adenocarcinoma	4	Metastases to brain
Adenocarcinoma	2	Metastases to larynx; lung
Papillary adenocarcinoma	1	Recurrent local infiltration
		Nonthyrotoxic Group (36 Cases)
Adenocarcinoma	4	Metastases to pelvis
Adenocarcinoma	2	Metastases to cervical glands
Adenocarcinoma	2	Death in 2 years
Adenocarcinoma	2	Metastases to liver and skull
Adenocarcinoma	3	Metastases to cervical glands
Adenocarcinoma	2	Metastases to supraclavicular glands
Fibrosarcoma	3	Death in 2 months
Adenocarcinoma	2	Metastases to brain, liver, spleen and cervical glands; death
Adenocarcinoma	2	Death in 1 year
Adenocarcinoma	3	Metastases to cervical glands; mediastinum; death in 2½ years
Adenocarcinoma	3	Metastases to lungs; death in 9 months
Adenocarcinoma	2	Local metastases; death in 4 months
Papillary adenocarcinoma	2	Metastases to parotid gland; death in 4 years
Squamous cell carcinoma	4	Death in 1 year
Adenocarcinoma	2	Metastases to supraclavicular glands and lungs; death in 1 year
Diffuse carcinoma	4	Death in 6 months

COMMENT

Out of our analysis of this series of 50 malignant thyroid tumors several facts emerge:

1. Thyrotoxicosis seems to be more frequently associated with adenocarcinoma of low or moderate grade of malignancy than with papillary forms of carcinoma.

2. Toxic symptoms are not produced by carcinoma in which the cells are completely dedifferentiated, that is, by the most malignant types.

68. Warthin, A. S.: The Constitutional Entity of Exophthalmic Goiter and So-Called Toxic Adenoma, Ann. Int. Med. **2**:553-570, 1928.

Such symptoms are also absent with growths composed of nonfunctioning cell forms, such as squamous epithelioma and fibrosarcoma.

3. The cells most capable of functioning and therefore of producing thyrotoxic symptoms are the common thyroid cells of small and moderate size. The large cell forms of thyroid neoplasm seem to be somewhat less prone to cause toxicity. In the thyrotoxic group only 14 per cent of tumors showed a large cell structure, whereas in the nonthyrotoxic group 25 per cent were composed of large cells.

4. Acinus formation was present in over 70 per cent of growths accompanying thyrotoxicosis.

5. The prognosis is more favorable for malignant neoplasms of the thyroid gland with than without toxic symptoms.

SUMMARY

A series of 50 cases of malignant disease of the thyroid gland is presented.

A study has been made of the thyrotoxicosis which accompanies a certain proportion of tumors of the thyroid gland.

An analysis has been made of the structural peculiarities of the neoplasms which are accompanied by thyrotoxic states.

It is suggested that certain histologic and cytologic criteria must be fulfilled by any tumor of the thyroid before it can produce thyrotoxicosis.

EMBRYOLOGY OF THE HIP JOINT

PRELIMINARY OBSERVATIONS

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AND
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The present preliminary study of the hip joint was made on a series of embryos and fetuses collected in cases of therapeutically interrupted pregnancies of varying duration.

It is felt that the majority of standard works dealing with embryology and developmental anatomy do not give sufficient information with regard to the development of the structures forming the hip joint to be of great value to the orthopedic surgeon, and this preliminary report may stimulate further work on a subject repelete with data capable of practical application.

METHOD

The embryo or fetus was split sagittally in the midline, after which the specimen was cut through the trunk in the horizontal plane just above the level of the hip joint. The hip joint was found to be on a level with the symphysis pubis anteriorly and at the level of the first or the second sacral segment posteriorly. Serial sections were cut just above this level in the horizontal plane and were continued through the entire thickness of the hip joint. In this way all structures were included. A few sections were lost; no attempt, therefore, has been made to perform serial reconstruction of the hip joint from serial sections, although the desirability of this method is admitted.

PROTOCOLS

SPECIMEN 1 (embryo aged about 6 weeks).—This embryo was studied by means of descending horizontal serial sections starting in the midabdominal region and continuing caudally. In some sections the cartilage of the ilium appeared. It was extremely primitive both histologically and morphologically, and no definite sacroiliac joint space was present. As the sections continued through the ilium one identified what was undoubtedly the primitive hip joint. The cartilages composing it were more or less formless, but there was some evidence of rearrangement of the ilium to form a slight concavity in which the cartilage of the femur rested. The space between the two cartilages was filled with undifferentiated cellular

From the Hospital for the Ruptured and Crippled, New York, and the Crippled Children's Hospital, Oklahoma City.

tissue, so that actually there was merely a suggestion of a joint space. There were no blood vessels in any of the cartilages, and the cotyloid ligament seen in the older embryos was not differentiated. There were some soft tissue buds which represented the lower limbs.

Fig. 1.—Sagittal section of a 6 week embryo, showing the primitive hip joint. The acetabulum is to the right.

SPECIMEN 2 (embryo aged about 10 weeks).—This embryo was not split sagittally as were the larger specimens. The sections commenced at the level of the first sacral vertebra. There were beginning calcification and ossification of the center of the iliac bone, but all the other structures were cartilaginous. The

sacroiliac joint appeared as a thin but well defined joint space containing blood vessels and embryonal connective tissue. The cartilages were surrounded by fibrous perichondrium composed of embryonal connective tissue, and the dorsal processes of the sacral vertebrae did not meet in the midline, the gap being bridged by connective tissue. There was a small center of ossification in the center of the body of each of the sacral vertebrae, and a small myxomatous area represented the corpus vertebrae, or the remnant of the notochord. The ossification of the iliac bone seemed to be greatest at the sacroiliac junction. As the serial sections were studied, the ilium became constricted into two portions; the anterior portion was triangular and assumed a close relation with the hip joint, as will appear in the further description. We refer to this anterior portion of the ilium as a part of the triradiate cartilage. In the further serial sections the cavity of the acetabulum appeared as a small circular space lined by flattened, condensed cartilage cells. About three fourths of the circumference was cartilaginous and one fourth was fibrous, the fibrous portions representing the primitive cotyloid ligament. The acetabular space was present before the head of the femur appeared, indicating that there was an appreciable joint width between the roof of the acetabulum and the head of the femur. The roof of the acetabulum was formed entirely by the ilium, and the triradiate cartilage was continuous with the superior ramus of the pubis. In the later sections the femoral head appeared as a club-shaped avascular cartilaginous structure. Small portions of the femoral shaft, which was partly ossified, were also observed. There was no well defined neck of the femur as seen in the older embryos, although there was a lateral protuberance corresponding to the greater trochanter. No joint capsule could be identified, the soft tissue in the vicinity being loose in arrangement. In deeper sections the ligamentum teres was encountered arising from the foveal region of the head, and it could be traced to its insertion in the acetabulum. It contained no blood supply.

Summary.—In the 10 week embryo all of the pelvic structures are formed in cartilage except for a center of ossification in the portion of the iliac bone opposite the sacroiliac joint. This corresponds to the position of greatest strain. None of the cartilages show a blood supply. The head and neck of the femur are club shaped and not particularly differentiated. The trochanter, however, is differentiated. There is little vascularization of any of the structures, although there are a few blood spaces in the periphery of the acetabulum and in the fibrous tissue around the head, in the location that would correspond to the neck if it were formed. There are fibrous strands near the acetabular region and the trochanteric region, but they can scarcely be identified as a capsule such as is seen in the 4½ month fetus. The hip joint is at the level of the symphysis pubis, but both the hip joint and the symphysis pubis seem to be at the level of the first sacral vertebra. The cotyloid ligament and the ligamentum teres are both formed. The latter does not posses a blood supply.

Specimen 3 (fetus aged about 14 weeks).—The early sections above the level of the hip joint showed a somewhat larger center of ossification of the ilium than did those of the embryo previously described. When the triradiate cartilage was encountered, it was noted that around its periphery there were several blood

channels. The acetabulum first appeared as a complete circle and later as about three fourths of a circle. It was lined by fibrous perichondrium. The head of the femur was composed entirely of cartilage and was far more shapely than that of the 11 week embryo. No synovial elements could be identified in either specimen.

Summary.—In the 14 week embryo the acetabulum, the femoral head and neck and the trochanter are formed of cartilage. The cotyloid liga-

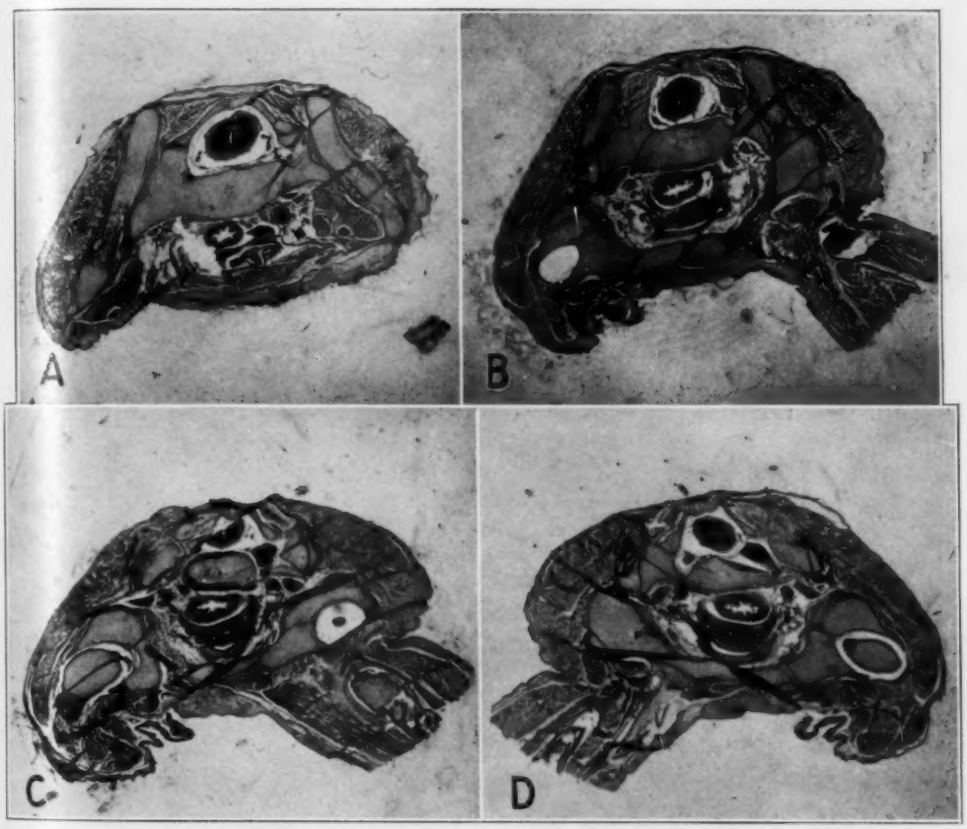

Fig. 2.—*A*, horizontal section through a 10 week embryo at the level of the sacroiliac joint. The iliac cartilage is undergoing ossification. The dorsal laminas are not fused. *B*, same embryo. The section shows the acetabulum on the left side at the level of the pubic symphysis anteriorly. Notice the well formed cotyloid ligaments and the absence of any blood supply to the cartilages. *C*, same embryo. The head of the femur is flattened and club shaped. The ligamentum teres is avascular. Notice the absence of a joint capsule. *D*, same embryo. The general features are the same. The blood supply of the head is more marked from the capsular side. The cotyloid ligaments are present.

ment and the ligamentum teres are well defined. The latter is vascular. The structures have a more nearly adult shape than the club-shaped head seen in the 10 week embryo. No well defined joint capsule is present. The fovea centralis is composed of myxomatous tissue.

The head is slighly vascular, the blood vessels being near its periphery and opposite the ligamentum teres. The acetabular cartilage is sur-

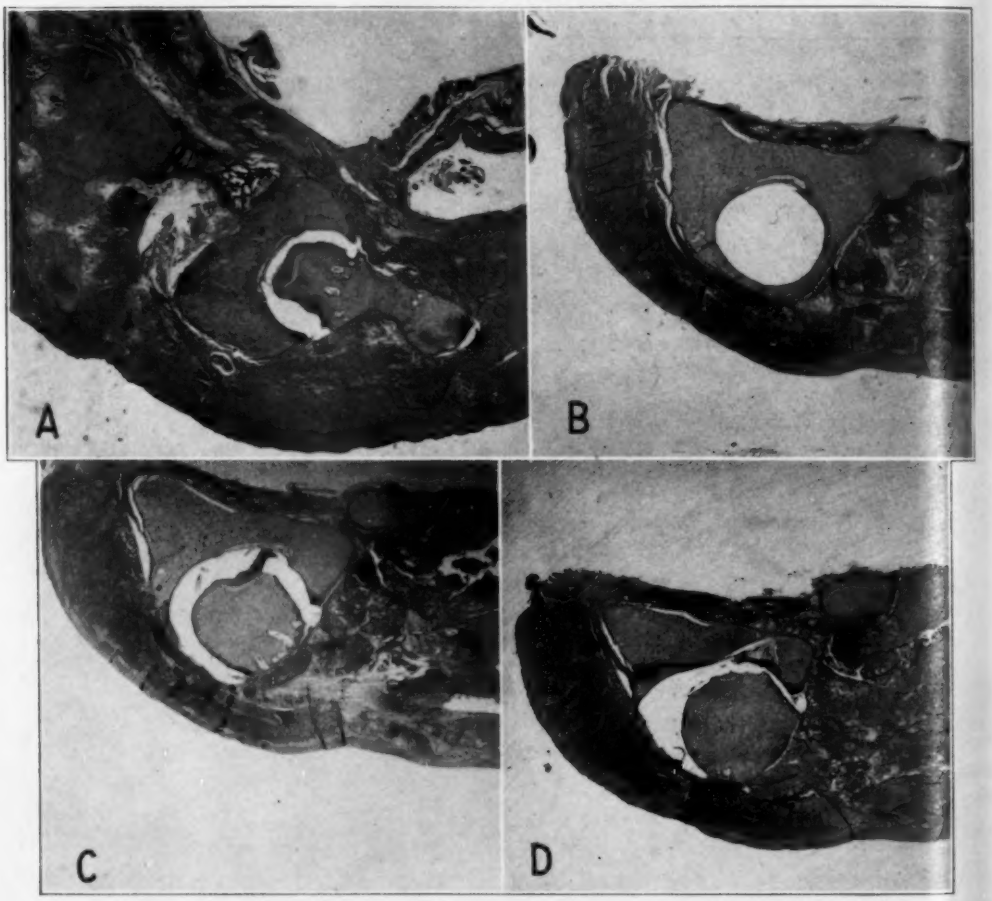

Fig. 3.—*A*, sagittal section through the hip joint of a 14 week fetus, showing the acetabulum and the ilium. Notice the blood supply of the intertrochanteric region. *B*, same fetus in horizontal section, showing the acetabulum and a portion of the pubic ramus. There is beginning vascularization of the acetabulum at the site of attachment of the ligamentum teres. *C*, same fetus, showing the head of the femur in the acetabulum. The ligamentum teres is readily seen. It has a slight blood supply, which is not apparent in this magnification. The joint capsule is still not formed. *D*, same fetus. Note the separate iliac and pubic components of the acetabulum.

rounded by fibrous perichondrium, which supplies a few invading blood vessels to its substance.

SPECIMEN 4 (fetus aged about 20 weeks).—In sections of the hip joint through the sacroiliac joint, the center of ossification of the ilium had expanded in all directions so that about three fourths of it was ossified. The sacroiliac joint space was wider and better developed than in the specimens previously described. The ilium was surrounded by fibrous periosteum in which considerable new bone formation was apparent, and this periosteum was extremely vascular, supplying the bone with new blood vessels. The acetabulum, head, neck and trochanter were composed of cartilage, but a small center of ossification appeared in the posterior superior, or iliac, portion of the acetabulum. The acetabulum was surrounded on its nonarticular surface by thick fibrous perichondrium, and this was continuous at the rims of the acetabulum with well formed cotyloid ligaments. The blood supply of the acetabulum was extremely profuse, and several vessels entered its substance from all regions of the periphery. The capsule of the hip joint could be identified as thin strands of wavy fibers originating from the acetabular edges and inserting into the superior and inferior portions of the femoral neck. (We have not attempted to reconstruct anatomically the blood supply of the head and neck, but it is obviously derived from vessels which enter by way of the capsule near its insertion into the neck.) In this specimen, blood vessels entered on both the upper and the under surface of the neck and appeared to anastomose freely. The head was surrounded by a few rows of flattened cartilage cells. It was possible to determine that the head was moderately vascular, the vascular spaces in general being away from the convex area. The ligamentum teres and the fovea centralis were recognized, and both these and the area of insertion of the ligament were vascular. The cotyloid ligaments were well formed.

The 20 week fetus showed the following developmental changes from the appearance of the 14 week embryo: The cartilages of the acetabulum were surrounded by a vascular rim of perichondrium. The femoral head was more shapely and extremely vascular. There were a well defined neck and trochanter and a beginning joint capsule. The concavity of the acetabulum opposite the foveal portion of the head showed a vascular layer which represented the site of emergence of the ligamentum teres. The head, as has been mentioned, was composed of hyaline cartilage with a peripheral rim of flattened cartilage cells, and at its junction with the neck it was covered with a layer of vascular connective tissue which undoubtedly represented primitive synovium. The trochanter seemed to receive an independent blood supply from the muscles of its lateral aspect and also received some blood supply from blood vessels of the capsule. The impression received was that the majority of the blood vessels supplied the head and trochanter and that the neck of the femur derived a less profuse blood supply from an anastomotic cross circulation. The capsule was even and delicate and was continuous with the perichondrial tissues surrounding the acetabulum. In one section the femoral head and neck, trochanter and ligamentum teres were noted. The ligamentum teres was liberally supplied by blood vessels which were linked up with those of the fovea centralis, but these blood vessels did not seem to penetrate the cartilage of the femoral head. The blood vessels in the ligamentum teres could be traced to a plexus in the acetabulum. There were some zones of slight calcification of the cartilage of the femoral head in the areas related to the most profuse blood supply; ossification was not seen.

Summary.—The 20 week embryo shows the structures of the hip joint in a fairly mature state. The shape of the head, neck and trochanter is similar to that of these structures in the infant. The capsule

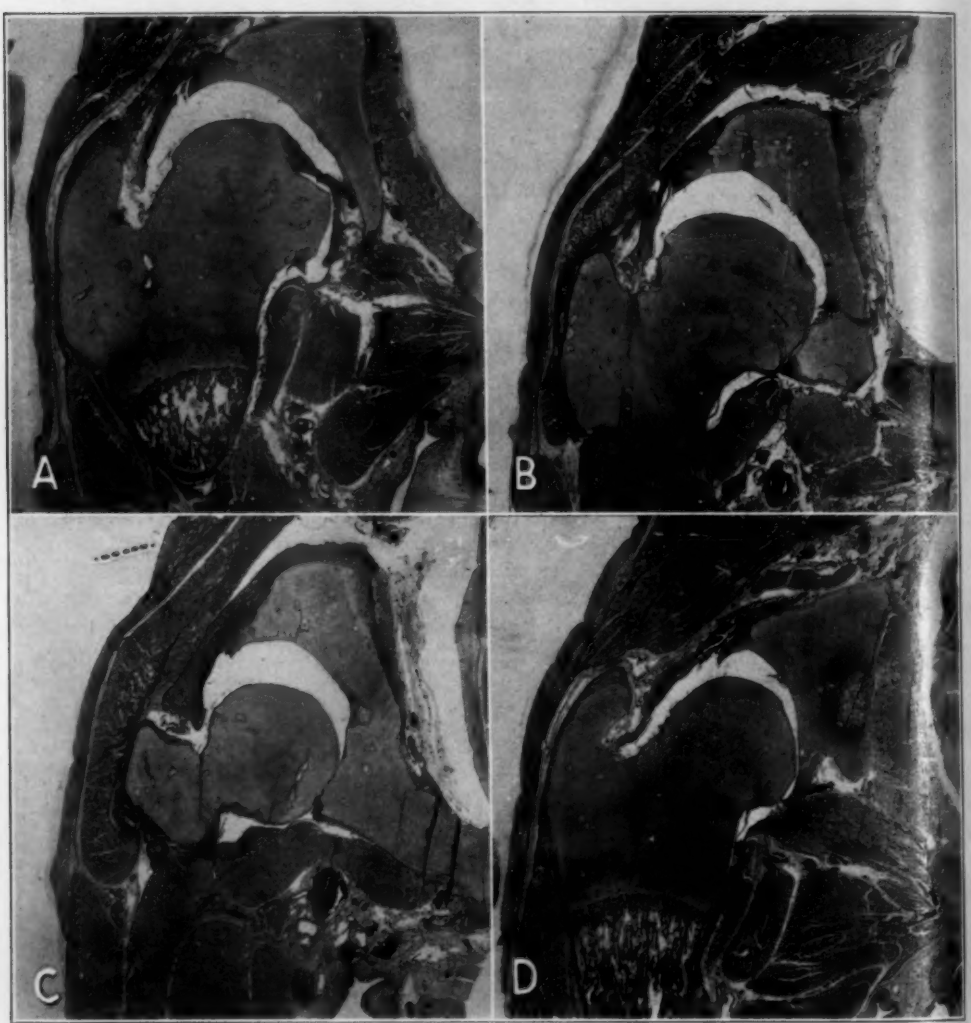

Fig. 4.—*A*, 20 week fetus, showing the head, neck and trochanter of the femur and the acetabulum. Notice the profuse blood supply of all the cartilages. The ligamentum teres is seen and also contains a profuse blood supply. The capsule may be seen for the first time, inserting into the notch between the neck and the trochanter. There is a vascular membrane covering the surface of the upper end of the neck; this represents the primitive synovium, not readliy seen in the low magnification. *B*, same fetus, showing the same complete acetabulum. *C*, same fetus. Notice that the hip joint is at the level of the pubic symphysis. D, same fetus, showing the center of ossification in the acetabulum.

of the hip joint can be identified for the first time. The capsule brings with it a profuse blood supply, which enters the head at its junction with the neck on both its superior and its inferior surface. These vessels penetrate the head in various directions, tending to converge near the convex portion. Small zones of calicfication of the cartilage are identified, but true ossification does not appear until later. The first center of ossification seems to develop in the acetabulum—in its posterior superior portion, the iliac portion. The cavity of the acetabulum, the ligamentum teres and the fovea centralis are rich in blood vessels, but these blood vessels do not seem to penetrate into the femoral

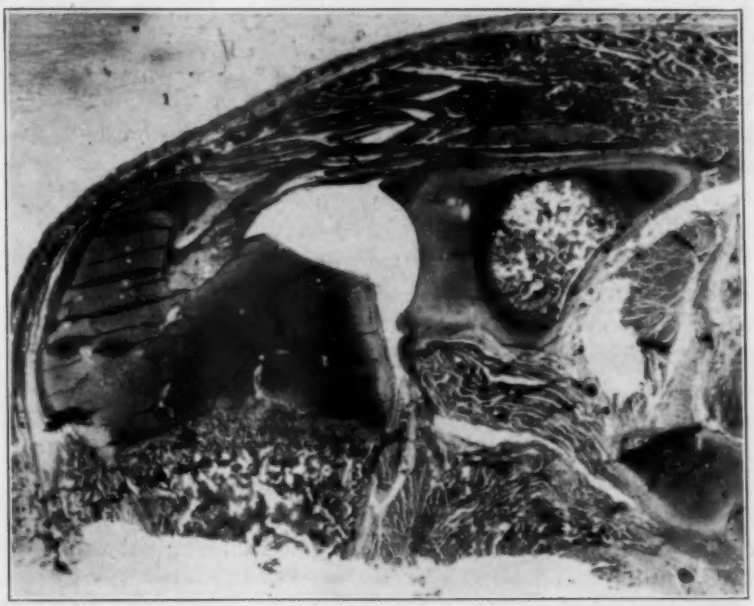

Fig. 5.—Fetus of 30 weeks. There are no striking changes from the appearance described for the 20 week fetus, but the structures are larger. The center of ossification in the acetabulum is somewhat larger. Some of the head is missing.

head. A structure identifiable as primitive synovium makes its appearance simultaneously in the acetabulum, surrounding the insertion of the ligamentum teres, and in the upper and under surfaces of the neck at the reflection of the joint capsule.

SPECIMEN 5 (fetus aged about 25 weeks).—The structures entering into the formation of the hip joint were slightly larger than in the fetus previously described. The femoral head and neck and the greater trochanter were all present in cartilages, and over the superior and inferior aspects of the neck the vascularity of the primitive synovium was more apparent than in specimen 4. The ligamentum teres and the fovea centralis were better developed. The femoral head appeared to lie somewhat anterior to a plane through the center of the acetabulum and to

suggest a certain degree of torsion of the neck of the femur. In other respects the appearance did not differ appreciably from that of specimen 4.

SPECIMEN 6 (fetus aged about 30 weeks).—The femoral head and neck and the trochanter were all present as cartilage, with a primitive epiphysial line fairly well down the shaft (about the level of the lesser trochanter). The acetabulum possessed a well formed center of ossification, but it was extremely shallow. The cartilages of the head and trochanter were more definitely formed, and some of the blood vessels extended down to the epiphysial line, where they probably anastomosed with the nutrient artery. The primitive synovium of the femoral neck was even more vascular than that previously seen. The neck was short and stubby, and the greater trochanter appeared to extend upward to about the level of the top of the femoral head, giving the neck a coxa vera attitude. The joint capsule, while better developed than in the specimens previously described, was not a thick, fibrous structure. In other respects there were no striking differences from the 25 week fetus.

GENERAL SUMMARY

A preliminary review of the embryology of the hip joint studied by means of horizontal serial sections through the embryo or fetus has been made on a series of specimens, normal embryos and fetuses 6, 10, 14, 20, 25 and 30 weeks old being used.

In the 6 week embryo the cartilages of the ilium and femur are formless structures, and only a suggestion of the joint space exists.

In the 10 week embryo the iliac cartilage is well formed, as is the acetabular cavity, but the femoral head is club shaped and not well differentiated. The cotyloid ligament and the ligamentum teres are present, but no definite capsule is developed, and there is no vascularization of the cartilaginous structures.

In the 14 week fetus the shape of the femoral head and that of the acetabulum more closely resemble the shape of these structures in the infant. The cartilages show beginning vascularization, although the capsule still remains unidentified.

In the 20 week fetus the acetabulum begins to ossify, and ossification proceeds rapidly throughout the remainder of intrauterine life. The capsule is present and is vascular. The blood supply of the femoral head and neck and of the trochanter may in part be traced to blood vessels entering by way of the capsule. The trochanter receives an additional blood supply from the lateral muscles. The ligamentum teres can be noted, and the synovium appears in the acetabulum and around the neck of the femur. It becomes increasingly vascular in the older fetuses.

In fetuses up to 30 weeks the enlargement of the capsule and the increase in its vascularity have been traced. A certain amount of remolding of the femoral head and neck, so that they resemble these structures in the infant, has been described.

TENDER POINTS IN DISEASES OF THE RENAL PELVIS AND OF THE URETER

PERIPHERAL DISTRIBUTION OF UNILATERAL AND BILATERAL HYPERALGESIA AND ANATOMIC RELATIONS OF THE SPINAL NERVES AND MUSCLES INVOLVED

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The work of the physiologist Gaskell,[1] reported in 1886, on the distribution of afferent nerve impulses initiated by the viscera later received clinical interpretation by Ross.[2] Many observers contributed to its further development, among whom Head,[3] Mackenzie,[4] Morley[5] and Lennander[6] may be mentioned. Cutaneous areas were mapped out by a study of cutaneous superficial hyperalgesia, the distribution of the rash along the course of nerves in cases of herpes zoster and the direction of the subjective symptom referred pain. To Head is due the credit for mapping out the distribution of the afferent somatic nerves in cases of structural and functional changes in the pelvis of the kidney and the ureter. This accumulation of clinical data, however, has been based essentially on the zoning out of cutaneous areas by actual tactile approach, without complete consideration of the anatomic structures involved.

Though all this accumulated knowledge is based mainly on clinical and physiologic observations, the anatomists have been prone to accept it. The cutaneous and muscular response to visceral disturbances is based on a reflex, the intricate course of which is at present beyond actual physical demonstration. This point of view was clearly expressed by Gaskell as follows:

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1. Gaskell, W. H.: On the Structure, Distribution and Function of the Nerves Which Innervate the Visceral and Vascular Systems, J. Physiol. **7**:1, 1886.

2. Ross, J.: On the Segmental Distribution of Sensory Disorders, Brain **10**:333, 1888.

3. Head, H.: A Disturbance of Sensation with Especial Reference to the Pain of Visceral Disease, Brain **16**:1, 1893.

4. Mackenzie, J.: Contribution to the Study of Sensory Symptoms Associated with Visceral Disease, M. Chron. **16**:293, 1892; Symptoms and Their Interpretation, London, Shaw & Sons, 1909.

5. Morley, J.: Abdominal Pain, New York, William Wood & Company, 1931.

6. Lennander, K. G.: Observations on the Sensibility of the Abdominal Cavity, translated by A. E. Baker, London, John Bale, Sons & Danielsson, Ltd., 1903.

It is hopeless at present to follow any nerve or group of nerve-fibres through a mass of ganglion cells with which it is in connection; it is impossible by simple anatomical investigation to trace these nerve-fibres further; the course of a nerve's fibre can however be traced by its physiological action as well as by its histological characters.

The knowledge accumulated by the various observations and interpretations has laid down a foundation for these concepts. Further advance, however, must be made mainly on the basis of anatomic investigation aided by clinical and experimental support.

In this work, instead of the customary tactile method, the modus operandi chosen was elicitation of deep hyperalgesia by deep pressure on or in the vicinity of nerves or nerve fibers, such as is noted over McBurney's point in cases of acute appendicitis. In addition, one palpates for muscle spasm.

The recognition in cases of calculus of the ureter of a constant point of maximum tenderness, located about 1 inch (2.5 cm.) medial to the anterior superior spine of the ilium and a little above the inguinal (Poupart's) ligament, led me not only into further urologic studies but into studies in the anatomic laboratory.[7] This collateral study included the various muscles, nerves and arteries of the abdominal and related regions. It was hoped further to correlate the growing clinical knowledge with the corresponding anatomic observations, concerning which the standard textbooks of anatomy proved inadequate.

ANATOMIC RELATIONS

That a clearer grasp may be obtained of the intricate involvement of certain anatomic structures in the production of the ureteral reflex, this section on the anatomic relations is presented. Consideration will be given to the following structures: the branches of the lumbar plexus, such as the iliohypogastric, ilioinguinal and genitofemoral nerves, particularly their origin, course and distribution; the obliquus externus and internus and transversus and rectus abdominis muscles, and branches of the iliac and femoral arteries, especially the deep circumflex iliac artery.

The relations of these structures to each other and to the associated viscera will be included.

The truncal muscles may be divided into four groups, as follows:

1. The dorsal axial muscles—the posterior group involving the body, spinous and transverse processes of the vertebrae and ribs.

2. The posterior muscles of the abdominal wall and pelvis—the psoas, iliacus and quadratus lumborum.

7. I was permitted to study the students' dissections at the Long Island College of Medicine and also adjunct and independent dissection.

3. The lateral muscles of the abdominal wall—the obliquus externus, obliquus internus and transversus abdominis.

4. The anterior muscles of the abdominal wall—the rectus abdominis and the pyramidalis.

The longitudinal muscles are connected by means of an intercommunicating group of muscles, in the thorax by the intercostal muscles and in the abdomen by the obliquus and transversus muscles. These three groups of muscles (posterior, lateral and anterior) are innervated by spinal nerves arranged on an obviously segmental basis, as described by Head, and containing sensory, motor and sympathetic fibers. Cunningham [8] stated that there is fusion of the segmental myotomes in the longitudinal posterior muscles, which are supplied by a series of muscular branches derived from the posterior rami of contiguous nerves.

It is apparent that the association of the longitudinal and intercommunicating muscles may be of help in distributing nerve fibers in a perpendicular direction beyond the more or less segmental direction of the nerves derived from the cerebrospinal nervous system.

This is further aided by the anastomosis and plexus formation in the obliquus internus muscle of individual branches of the lower intercostal nerves, the branches of the first lumbar nerve and whatever nerve filaments are carried by the deep circumflex iliac artery in its course upward.

Nerves.—The first lumbar nerve is a motor and sensory nerve, emerging from the intervertebral foramen, which sometimes (in 50 per cent of cases) receives a small branch from the twelfth dorsal nerve. It also has a relation to the sympathetic nervous system, by way of the gray rami communicantes, receiving branches from one or two sympathetic ganglions (frequently one ganglion sends branches to two nerves). The white rami communicantes, either independently or incorporated with the corresponding gray rami, join the upper part of the lumbar region of the sympathetic trunk. The first lumbar nerve then divides in the substance of the psoas muscle into an iliohypogastric and an ilioinguinal nerve, the iliohypogastric lying above and the ilioinguinal below. Two independent roots from the first and second lumbar nerves unite to form a slender trunk, the genitofemoral nerve.

In their composition, course and distribution these nerves resemble closely the lower thoracic nerves, with which they are in series. Many authors classify the first lumbar nerve as the thirteenth dorsal nerve because of this similarity.

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8. Cunningham, D. J.: Text-Book of Anatomy, ed. 5, edited by A. Robinson, New York, William Wood & Company, 1928.

Iliohypogastric Nerve: There are varying opinions regarding the origin of this nerve,[9] but Bardeen and Elting [10] claimed to have found it originating from the first lumbar nerve in 183 of 246 instances, which is the largest series reported; from the twelfth dorsal nerve in 63 of 246 dissections, and from the eleventh dorsal nerve in rare instances (1 case).

The iliohypogastric nerve rests on the quadratus lumborum muscle and behind the kidney, not far from the inferior pole. It pierces the fascia and lies between the transversus abdominis and the obliquus internus muscle, hugging mainly the latter. In this location the nerve frequently spreads out over a wide area, and a free anastomosis and plexus formation exist. In 8 instances, I have observed an anastomosis with the eleventh dorsal nerve twice, with the twelfth dorsal nerve five times and with the ilioinguinal nerve three times. Cruveilhier has also observed frequent anastomosis with the twelfth dorsal nerve. In 12 dissections the iliohypogastric nerve was found five times within the iliac fossa.

When the internal oblique muscle was folded over, it was observed that the deep circumflex iliac artery arises from the lateral side of the external iliac artery and occasionally from the femoral artery, immediately above the inguinal ligament. Its course is above the lower border of this ligament, enclosed in a fibrous canal formed by the union of the fasciae of the transversalis and the iliac muscle. It runs laterally and upward to the anterior superior spine of the ilium. A little beyond this it pierces the transversus abdominis muscle and is continued between the transversus and the obliquus internus muscle. Two branches are given off: (1) a muscular branch, which ascends vertically to the muscles of the abdominal wall to anastomose with the lumbar and epigastric arteries, and (2) cutaneous branches, piercing the muscles and terminating in the skin over the crest of the ilium to anastomose with other vessels.

The deep circumflex iliac artery, the iliohypogastric nerve, occasionally the ilioinguinal nerve and in rare instances the twelfth dorsal nerve travel obliquely in the same plane, but in opposite directions. They frequently cross. There is an intricate and varying interinvolvement of these structures, which is summarized in table 1. I have seen an extensive plexus of nerves forming loops, networks and rings over a wide area embracing the lower four intercostal nerves, some fibers

9. Hovelacque, A.: Anatomie des nerfs craniens et richidiens et du système grand sympathique, chez l'homme, Paris, Gaston Doin & Cie, 1927.

10. Bardeen, C. R., and Elting, A. W.: A Statistical Study of the Variations in the Formation and Position of the Lumbo-Sacral Plexus in Man, Anat. Anz. **19**:124, 1901. Bardeen, C. R.: A Statistical Study of the Abdominal and Border-Nerves in Man, Am. J. Anat. **1**:203, 1901-1902.

of which terminate within the plexus, others form a loop to recommunicate with each other and still others anastomose with their own or other branches, terminate in the deep circumflex iliac artery or

TABLE 1.—*Relation of Lower Spinal Nerves to Deep Circumflex Iliac Artery (18 Dissections)*

	Number of Instances	Crossing of Deep Circumflex Iliac Artery by Nerve					
		Main Trunk, Number of Instances		Muscular Branch Number of Instances		Cutaneous Branches, Number of Instances	
		Anteriorly	Posteriorly	Anteriorly	Posteriorly	Anteriorly	Posteriorly
Iliohypogastric nerve	13	3	1	7	8	9	5
Ilioinguinal nerve	5						
Twelfth dorsal nerve	3						
Total	21						
Summary A	10	One spinal nerve crossed artery					
	5	Two spinal nerves crossed artery					
	1	Three spinal nerves crossed artery					
Summary B	5	Spinal nerves passed anterior to artery					
	3	Spinal nerves passed posterior to artery					
	2	Spinal nerves passed anterior, then posterior, to branches of artery					
	3	Spinal nerves passed posterior, then anterior to branches of artery					
Branch of iliohypogastric nerve	4	Terminated in deep circumflex iliac artery					
Branch of iliohypogastric nerve	2	Coursed parallel to main trunk of deep circumflex iliac artery					
Formation of nerve plexus	7	Involved deep circumflex iliac artery					

TABLE 2.—*Relation of Point of Emergence* of the Iliohypogastric Nerve from the Internal Oblique Muscle to the Anterior Superior Spine of the Ilium (23 Dissections)*

Inches	Mesial to the Anterior Superior Spine		Inferior to the Anterior Superior Spine	
	Number of Instances	Percentage of Cases	Number of Instances	Percentage of Cases
0.5	2	8.7	2	8.7
1.0	14	60.9	3	13.0
1.5	4	17.4	2	8.7
2.0	3	13.0	1	4.4
On level with anterior superior spine	..	....	15	65.2
Total	23	100.0	23	100.0

* This point corresponds to the point of maximum tenderness.

continue as a branch running along the course of the artery. All of these fibers come into direct contact with the deep circumflex iliac artery.

The point of emergence of the iliohypogastric nerve from the obliquus internus muscle varies in relation to the anterior superior spine of the ilium (table 2).

The iliohypogastric nerve becomes cutaneous 1.5 inches (3.8 cm.) above the subcutaneous inguinal ring. The branches of the iliohypogastric nerve are: 1. A muscular branch to the muscles of the abdominal wall, including a branch to the pyramidalis muscle, which is also supplied by a branch of the twelfth dorsal nerve. Sometimes a branch is given off to the rectus abdominis muscle (in 2 of 5 cases, according to Ruge; in 14 of 112 cases according to Bardeen). Eisler followed the nerve filaments to the great tendinous insertion of the rectus muscle.

2. A lateral cutaneous branch (similar to that of an intercostal nerve) to the lateral side of the buttock.

3. An anterior cutaneous branch to the skin of the anterior abdominal wall, below the level of the last thoracic nerve and above the os pubis.

Anastomosis. The branches to the internal oblique muscle on its deep surface anastomose with the filaments coming from the last four intercostal nerves, forming a veritable plexus (Hovelacque).

Ilioinguinal Nerve: This nerve is the second branch given off from the first lumbar nerve. It may also receive fibers from the last thoracic nerve. Not infrequently the iliohypogastric and the ilioinguinal nerve are represented for a longer or shorter part of their course by a single trunk. When separate, the nerve takes a course similar to that of the iliohypogastric nerve, but at a lower level, as far as the anterior abdominal wall. The ilioinguinal nerve was missing in 26 of 100 plexuses examined by Severeano. There is a variation in origin. The nerve was observed by Bardeen and Elting to arise from the first lumbar nerve in 229 of 246 instances. Ancel and Sencert made the same observation in 63 of 64 instances. The nerve has also been observed to arise from the twelfth dorsal nerve only or to receive at the same time a branch from the first lumbar nerve (in 113 cases by Bardeen and Elting).

The caliber of the ilioinguinal nerve is generally 1 to 1.5 mm.; that of the iliohypogastric nerve is at least 2 mm. The abdominal branch is very short, and not exceptionally loses itself in the large muscles of the anterior abdominal wall. I have also observed (in 7 of 11 instances) that it anastomosed frequently with the twelfth dorsal nerve, the iliohypogastric nerve and the ilioinguinal nerve and engaged itself in plexus formation and looping. Most frequently it was observed to go to the scrotum (6 instances) and occasionally to the pubis (2 instances). It was also seen to unite with the iliohypogastric nerve (5 of 11 instances). Occasionally the ilioinguinal nerve is very small and ends by joining the iliohypogastric nerve; when this occurs, a branch from the iliohypogastric nerve takes the place of the ilioinguinal nerve, or the ilioinguinal nerve may be absent (Gray [11]).

11. Gray, H.: Anatomy, Descriptive and Applied, ed. 18, Philadelphia, Lea & Febiger, 1910.

Course. The nerve lies between the transversus and the obliquus internus muscle and pierces the obliquus internus farther forward and lower than does the iliohypogastric nerve; it distributes branches to this muscle and accompanies the spermatic cord through the subcutaneous inguinal ring.

Branches. The ilioinguinal nerve distributes cutaneous branches to (1) the anterior abdominal wall over the symphysis pubis, (2) the thigh over the proximal and medial parts of the femoral triangle and (3) the superior part of the scrotum and the root and dorsum of the penis (of the mons veneris and the labium majus in the female).

The branches last mentioned are contiguous to branches of the perineal and pudendal nerves. As to the genital branch, it is not rare to see it fuse with the genital branch of the iliohypogastric nerve (Hovelacque). The ilioinguinal nerve possesses no perforating branches.

Genitofemoral Nerve:[8] This nerve arises from the first and second lumbar nerves and unites in the substance of the psoas major muscle to form a slender trunk. It appears on the posterior abdominal wall, lying on the psoas major muscle and extending downward on the lateral aspect of the common and external iliac vessels and behind the ureter to the inguinal ligament. At a variable point above that ligament it divides into two branches, as follows:

1. The external spermatic branch (small nerve) crosses the termination of the external iliac vessels and, together with the ductus deferens and the testicular and external spermatic vessels, enters the inguinal canal through the abdominal inguinal ring. It terminates by supplying small branches to the skin of the scrotum and the adjacent part of the thigh. In the female it accompanies the round ligament to the labium majus. During its course it gives off small branches to (1) the external iliac artery and (2) the cremaster muscle and communicates with (3) the spermatic plexus of the sympathetic nerve.

2. The lumboinguinal branch extends to the thigh, lying on the lateral aspect of the femoral artery. It becomes cutaneous by passing through the fossa ovalis or through the iliac portion of the fascia lata and supplies an area of skin over the femoral triangle lateral to that supplied by the ilioinguinal nerve. It communicates in the thigh with a branch of the femoral nerve and gives off minute branches to the femoral artery.

Muscles.—Obliquus Externus Abdominis Muscle: This muscle, being voluminous, has been termed by the French the *grand oblique.* It is musculoaponeurotic, the lateral part being muscular and the ventral part aponeurotic. Its origin is muscular, and it terminates in an aponeurosis on a level with the ninth costal cartilage and the anterior superior spine of the ilium. I found that the distance between this muscular edge and the lateral margin of the rectus muscle varied as

follows: no space, 1 instance; 2.5 cm., 5 instances, and 3.75 cm., 2 instances. In 5 of 8 instances, therefore, there is 1 inch (2.5 cm.) space. The lower muscular edge was seen to be above the anterior superior spine in 7 of 10 instances and below it in 2 instances. These measurements were taken at the level of the twelfth rib.

Obliquus Internus Abdominis Muscle: This is a broad, thin sheet of muscle which lies between the external oblique and the transversus muscle. I noted that its muscular part extended to the lateral edge of the rectus muscle in 11 of 13 instances and 1.25 cm. lateral to the edge of the rectus muscle in the remaining 2 instances. This muscle is apparently not responsible for the fascial space previously described.

Transversus Abdominis Muscle: This muscle terminates in an aponeurosis, which is widest at the level of the interval between the last rib and the iliac crest. The following variations in the extent of this interval were observed in 9 instances: (1) up to the edge of the rectus muscle, in 1 instance; (2) 2.5 cm. lateral to the edge of the rectus muscle, in 7 instances, and (3) 3.75 cm. lateral, in 1 instance.

In summarizing this small series, it was observed that there was a striking similarity between the aponeurotic interval of the obliquus externus and that of the transversus abdominis muscle.

ZONES

The anatomic data previously presented require clinical application to be of practical value.

In the muscles of group 1 (the dorsal axial muscles) elicitation of the well known Murphy sign [12] may depend apparently on deep hyperalgesia of the area over these muscles, which are supplied by the posterior rami of the regional spinal nerves. Costovertebral tenderness depends, I believe, on pressure over the twelfth dorsal nerve, which enters into the formation of the first lumbar nerve. From investigations now in progress, I believe that the first lumbar nerve is more concerned in the production of this hyperalgesia than is the twelfth dorsal nerve.

I am of the opinion that there is spasm and perhaps hyperalgesia of the muscles of group 2, which consist of the psoas, the iliacus and the quadratus lumborum muscle. I have been unable to find any reference to such hyperalgesia in the literature.

Groups 3 and 4 are the two groups of muscles described in this paper. Group 3 consists of the lateral muscles of the abdominal wall, the obliquus externus and internus and the transversus abdominis, and group 4 consists of the anterior muscles, the rectus abdominis and the pyramidalis. In this study two methods were used for palpation of the abdomen: Muscular spasm and muscular tenderness were elicited by

12. Murphy, J. B.: Murphy's Surgical Clinics, Philadelphia, W. B. Saunders Company, 1912, vol. 1, p. 459.

a moderate diffuse pressure with the flat of the hand; for deep hyperalgesia more localized pressure with the finger was used. These muscular signs are generally pronounced in the posterior group, moderate in the lateral group and mild in the rectus muscles of the abdominal wall. With the patient prone, the fleshy fibers of the obliquus externus muscles, if in spasm, can be palpated as a distinct edge. This edge is located about 1 inch (2.5 cm.) lateral to the margin of the rectus abdominis muscle. Normal variations of muscular development modify this finding. The depression between the obliquus externus and the rectus muscle is termed the fascial space.

The spasm and tenderness of the external oblique muscle varies in different parts, being most pronounced above the crest of the ilium, where its nerve supply is abundant, and least marked or absent at the upper part of the muscle. In contrast, the hyposensitive fascial space separates the mildly tender edge of the rectus muscle from the more tender fleshy edge of the external oblique muscle. Tenderness is usually greatest along the fleshy edge of the external oblique muscle. The rectus muscle also possesses a varying degree of muscle spasm and tenderness. For convenience, this muscle has been divided into a medial and a lateral edge and a body. As a rule there are slight tenderness of the medial edge, moderate tenderness of the lateral edge and more marked tenderness of the intervening body. This variation is dependent, I believe, on the nerve supply. The intercostal nerves pierce the deep surface of the rectus muscle and spread out close to the lateral edge. The nerves extend to adjoining segmental areas of the rectus muscle and emerge to become cutaneous. This accounts for the inequality of tenderness in this muscle.

The rectus abdominis, like the external oblique, muscle manifests the greatest amount of spasm and tenderness in its lowermost parts. The upper limits of hyperalgesia may extend as high as the eighth or ninth dorsal nerve, and occasionally higher (the umbilicus corresponds to the tenth dorsal nerve).

Deep hyperalgesia has been observed to correspond with the course, distribution and emergence of the nerves and nerve fibers involved in the reflex.

I have observed five points of deep hyperalgesia, including the point of maximum tenderness. These were:

1. A point at the level of the first lumbar nerve, lateral to the spines of the vertebrae.

2. The posterior part of the peak of the crest of the ilium. This corresponds, I believe, to the course of the first lumbar nerve within or above the hollow of the iliac fossa and its emergence through the transversus muscle.

3. The point of maximum tenderness, which is located about 1 inch (2.5 cm.) medial to and on a level with the anterior superior spine of the ilium.[13] Variations will correspond with the data in table 2. Tenderness at this point, I believe, is produced by the emergence of the iliohypogastric nerve from the internal oblique muscle. There is also a less clearly defined area of tenderness around this point, about the size of a half-dollar. This, I believe, corresponds to formation of a plexus containing the twelfth dorsal or first lumbar nerve.

4. A point directly above and lateral to the crest of the pubis. Tenderness at this point is apparently due to the termination of a branch of the first lumbar or twelfth dorsal nerve.

5. Within the femoral (Scarpa's) triangle, along the femoral sheath. This corresponds, I believe, to the point of emergence of the genitofemoral nerve and other fibers of the first lumbar nerve. This point has been described by Livingston,[14] who elicited tenderness in this region by pinching the skin.

In this study the reflex has been followed to the femoral triangle. In the lower extremity these points have not been worked out in detail, but in general it may be stated that other points of tenderness have frequently been found along the inner part of the thigh, in the popliteal space, in the inner part of the calf and in the knee and ankle, particularly in the mesial rather than in the lateral aspect.

In addition, a belt of hyperalgesia, tapering to about 2 inches (5 cm.) and corresponding to the twelfth dorsal and first lumbar nerves, which connect all the points of tenderness previously mentioned, radiates over the crest of the ilium, above the inguinal ligament, to the pubis and to the femoral triangle and then along the course previously mentioned.

I have observed patients who complained of pains in the hip, knee and ankle joints during and after an attack of calculus of the ureter, which either improved or disappeared after the attack had subsided. I am of the opinion that such symptoms are not truly arthritic, but are manifestations of nerve irritation in the region of these joints.

All of the previously mentioned findings have been observed to be bilateral, with variations in frequency depending on the underlying pathologic condition. Even in the presence of a unilateral lesion a milder contralateral reflex was observed. This will be considered later in more detail.

13. After completion of this work, description of a somewhat similar point was found in the literature (Barney, J. D.: A Point in the Clinical Diagnosis of Ureteral Calculus: A Preliminary Report, Ann. Surg. **107**:636 [April] 1938).

14. Livingston, E. M.: A Clinical Study of the Abdominal Cavity and Peritoneum, New York, Paul B. Hoeber, Inc., 1932, pp. 633-634.

These studies have been made on patients presenting signs referable to the abdominal wall analogous to those associated with chronic or subacute intra-abdominal conditions rather than with the tense muscles of the "acute abdomen."

The expression "Tenderness is found along the course of the ureter" is explicable by what is known as vertical continuation downward of Tourneur's point.[15] It is my opinion that this vertical line of tenderness corresponds to the deep hyperalgesia observed at or about the lateral margin of the rectus abdominis muscle.

In ureteral disturbances, pain and hyperalgesia have frequently been found to be limited to either the right or the left side. In intraperitoneal conditions, however, such demarcation is not so evident.

TABLE 3.—*Analysis of One Hundred Cases in Which Routine Cystoscopic Examination Was Done for Suspected Urologic Conditions*

Group 1 Definite Diagnosis	No. of Cases	Group 2 Presumptive Diagnosis	No. of Cases	Group 3 No Diagnosis of Renal or Ureteral Disease	No. of Cases
Calculus	17	Obstruction of ureter	12	Hematuria	12
Ureter	12	Hydronephrosis	9	No diagnosis	3
Pelvis	3	Ptosis	3	Pathologic condition of bladder	7
Kidney	2	Pyelitis of pregnancy	3	No findings	3
		Tumor of kidney	4	No diagnosis with positive findings	12
		Pathologic condition of bladder	9		
		Tuberculous pyonephrosis	1		
		Retropsoas abscess	1		
		Infarct of kidney	1		
		Spasm of ureter	2		
		Scoliosis	1		
Total	17		46		37

ANALYSIS OF ONE HUNDRED CASES (TABLE 3)

This report is based on 100 cases in which routine cystoscopic examination was made at the Cumberland Hospital, under the direction of Dr. John E. Jennings, director of surgery, and Dr. R. E. Kinloch, attending urologist, and at the Israel-Zion Hospital, under the direction of Dr. William Linder, chief of surgery, and Dr. Abraham Hyman. Several of my private cases were included in the study.

The examinations were performed by the urologists of the service and consisted of the usual routine including intravenous and retrograde pyelographic examination and roentgen and laboratory examinations. Many of the patients were operated on. I was present at each cystoscopic examination, and the hospital records have been transcribed to my personal notes, for the sake of completeness.

15. Piersol, G. M.: Piersol's Human Anatomy, Including Structure and Development and Practical Considerations, edited by G. C. Huber, ed. 9, Philadelphia, J. B. Lippincott Company, 1930, pp. 1898-1901.

In 14 of the 17 cases in group 1, which consists entirely of cases of calculus, the diagnoses were made by the points and areas of hyperalgesia previously enumerated and they coincided with the final diagnoses, which were made by urologic methods. The calculi in these cases were located as follows: on the right side, in 9; on the left, in 7, and bilaterally in 1 case. The cases may be further subdivided into those in which the calculus occurred in the ureter (12 cases), in the pelvis of the kidney (3 cases) and in the kidney (2 cases).

Analysis of table 3 reveals that in group 2, or the cases in which no calculus was present, the tender points and areas indicated the involvement in 71.8 per cent of the cases, as proved by urologic methods of diagnosis. In the cases of hematuria in group 3 the difficulty in arriving at a diagnosis makes further comment inadequate. It may be mentioned, however, that mild hyperalgesia was frequently elicited, which coincided with other clinical findings. The conclusions were suggestive, but not definite.

Group 3, in which no definite diagnosis was established, will not be considered here, except to say that the cases in which the findings were not significant served as ideal controls. In the group in which the diagnosis was presumptive the following case will show the difficulty in establishing an accurate diagnosis.

The patient in case 9, a woman, was admitted to the orthopedic service at the Israel-Zion Hospital on Dec. 27, 1933, having been admitted to the same service on three previous occasions for treatment of scoliosis, relief of which was attempted by the application of plaster jackets. An appendectomy was performed in 1923 and a right salpingectomy for an ectopic pregnancy in 1929. The patient complained of burning on urination, frequency of voiding, nocturia, stoppage of urinary flow and pain extending posteriorly on the left side over the lumbar region and radiating to the vulva and the thigh. Urologic examination revealed a slight spasm of the left ureter, and roentgen examination showed that the twelfth dorsal vertebra was wedge shaped, with a sharp angulation to the left and a corrugated left border.

Campbell [16] stated that "in spinal caries pressure on the nerve trunk produces pain at the periphery and also caries of the upper lumbar vertebrae may be mistaken for renal calculus (Woolsey)."

BILATERALITY

In cases in which the lesion is apparently unilateral, pain is frequently bilateral. This phenomenon has been termed "the renorenal reflex." Two theories have been advanced to explain it. One group of observers has contended that there is actually a bilateral pathologic condition, though on only one side is it actually demonstrable; another

16. Campbell, W. F.: Surgical Anatomy, Philadelphia, W. B. Saunders Company, 1921.

group has contended that there is a unilateral pathologic condition which produces a contralateral reflex. The physical basis for these assumptions has been arrived at subjectively, for the most part.

In my analysis, based on 100 cases, this problem has been approached from the objective point of view, on the basis of deep hyperalgesic zones rather than of pain per se. In group 1, 17 cases of proved unilateral calculus were reviewed. Although this group of cases is small, the observations were carefully made and were supported by data in other cases not recorded here. Bilateral signs were observed in 5 of these 17 cases, or 29.4 per cent (table 4). As the investigation of the reflex becomes more detailed, the percentage should be higher.

In reviewing this group it is noted that the percentage of instances in which there was a bilateral reflex varies from 8.3, in the cases of undiagnosed hematuria, to 29.4 in the cases of calculus of the ureter. On comparison of these two extremes it is obvious that the intensity of the impulse may play the important role. In cases of hematuria the reflex

TABLE 4.—*Bilaterality of the Renorenal Reflex*

Group	Lesion	No. of Cases	Bilateral Reflex	Percentage
1	Calculus	17	5	29.4
2	Ptosis	3	1	33.3
	Hydronephrosis	9	3	33.3
	Obstruction of ureter	12	3	25.0
	Pyelitis	3	1	33.3
3	Hematuria	12	1	8.3

is mild, whereas in cases of calculus it is pronounced. The variation apparently depends on the underlying pathologic condition. Patients with ptosis, hydronephrosis, pyelitis or calculus possess the contralateral reflex in approximately the same percentage, whereas for patients with obstruction of the ureter the incidence is less and for patients with the hematuria the least. In conclusion, it may be stated that the greater the hyperalgesia, the more frequently the contralateral reflex appears. Pottenger [17] mentioned that the strength of the nerve impulse is sufficient to overcome the threshold of resistance.

Head also concluded that there is a tendency for both pain and tenderness to appear on the opposite side at the same spinal level.

PARAVERTEBRAL INJECTION

The following case, in which a paravertebral injection was given for a proved unilateral calculus of the ureter, is presented as evidence of the location, intensity and direction of pain produced by irritation of the twelfth dorsal and the first and second lumbar nerves during the course

17. Pottenger, F. M.: Symptoms of Visceral Disease, St. Louis, C. V. Mosby Company, 1930.

of the injection and the subsequent disappearance of previously mapped out areas of hyperalgesia on injection of procaine hydrochloride into the nerve roots. The injection is simultaneously a nerve-stimulating and a nerve-blocking process. The result is in agreement with the five postulates of Steindler[18] for the establishment of a causal relation between local pain and radiation.

J. O., a man aged 36, was admitted to the Israel-Zion Hospital on Sept. 16, 1937 with a history of three previous renal attacks. The first occurred in November 1936. The present attack began three days prior to admission, with sudden pains in the right renal region radiating to the pubis, the base of the penis, the testicle and the inner side of the thigh. The pain was intermittent and was accompanied by the usual symptoms of involvement of the urinary tract, including hematuria. The patient also complained of slight pain in the right hip, knee and ankle, and to a less extent of pain in the left knee and ankle and in the chest, particularly on the right side, on breathing. Urinalysis showed a 1 plus reaction for albumin, many red blood cells and occasional white blood cells. On cystoscopic examination an impassable obstruction was observed 5 cm. from the right ureteral orifice, and roentgen examination revealed an irregular calcific shadow. Ureterotomy was performed on October 20, with removal of a calcium calculus 4 mm. in diameter. On Jan. 3, 1938. a nephrectomy was performed for chronic pyelonephritis with superimposed acute cortical abscesses and a urinary fistula.

On Sept. 20, 1937, at 11:45 a. m., Dr. E. Salwen made a paravertebral injection of 2 cc. of 0.5 per cent procaine hydrochloride into the roots of the twelfth dorsal and the first and second lumbar nerves on the right side. Owing to irritation of the nerve roots by the needles, the patient noted a "belt" of severe pain beginning at the site of injection and shooting downward, above the inguinal ligament, into the pubis, the head of the penis and testicle, along the inner aspect of the lower extremity, through the hip, knee and ankle joints and the popliteal region to the anterior and posterior parts of the great toe. It was accompanied by less clearly defined pain in the abdomen, extending anteriorly to about the ninth dorsal segment. In an area about the size of a silver dollar, corresponding to the region of maximum tenderness, mesial to the anterior superior spine of the ilium, the pain was so intense that the patient, as he expressed it, felt "as if something burst."

Table 5 represents the various hyperalgesic areas and points on the right and left sides (bilateral reflex) before and after blocking of the twelfth dorsal and the first and second lumbar nerve roots, on the right with procaine hydrochloride. The paravertebral injections were completed at 11:45 a. m., and the following notes were made:

11:50 a. m.: There was no pain in the right lower quadrant. There was pain at the site of injection and in the penis.

12:00 noon: There was tenderness of the right rectus muscle. Tenderness was absent in the distribution of the ninth and tenth dorsal nerves and was plus-minus in that of the eleventh dorsal nerve. On the left side, tenderness was absent in the distribution of the ninth dorsal nerve, plus-minus in the area of the tenth and eleventh dorsal nerves and absent in that of the twelfth. There was no pain in the penis. There was slight burning on urination.

18. Steindler, A.: Differential Diagnosis of Pain Low in the Back: Allocation of the Source of Pain by the Procaine Hydrochloride Method, J. A. M. A. **110**:106 (Jan. 8) 1938.

12:10 p. m.: There were no pains in the previously painful areas, including the penis. The other intercostal nerves were considerably less tender.

12:20 p. m.: There was no burning on urination. There was no pain or tenderness in the abdomen or the lower extremities. All the areas of the left intercostal nerves were normal except that of the seventh dorsal, in which there was a plus-minus response. The patient breathed more freely, with no pain in either side of the chest on deep inspiration. There was persistence of a point of mild maximum tenderness.

12:25 p. m.: All the intercostal nerves were normal, including the left seventh dorsal nerve. There was no pain in either side of the chest, the abdomen or the lower extremities. All involved muscles were relaxed, including the posterior, lateral and anterior groups. The dorsal axial muscles were doughy to the touch,

TABLE 5.—*Somatic Hyperalgesia Before and After Paravertebral Injections* in the Twelfth Dorsal and the First and the Second Lumbar Nerve on the Right*

	Right Side			Left Side		
	Before	After 35 Min.	Following Day	Before	After 35 Min.	Following Day
First lumbar nerve (near vertebra)...	2+	—	1+	1+	—	±
Posterior to peak of crest of ilium....	2+	—	±	±	—	—
Maximum point.....	3+	∓	1+	1+	—	±
Inguinal belt.....	2+	—	+	±	—	±
Pubis.....	2+	—	—	∓	—	—
Femoral triangle.....	1+	∓	±	∓	—	—
Popliteal space.....	1+	—	±	±	—	—
Medial malleolus.....	1+	—	±	±	—	—
Lateral malleolus.....	±	—	∓	±	—	—
Rectus muscle: Medial edge.....	±	—	—	±	—	∓
Body.....	2+	—	±	1+	—	±
Lateral edge.....	1+	—	±	++—	—	∓
External oblique muscle edge:						
Upper part.....	1+	—	—	—	—	—
Lower part.....	2+	—	±	±	—	±

* Injection of 2 cc. of 0.5 per cent procaine hydrochloride into the nerve roots.

permitting distinct palpation of the surrounding bony landmarks. Prior to the injections all of these muscles had been spastic throughout.

At 9:00 a. m. on the following day, without any further medication or treatment, the patient felt considerably improved. The tightness in his chest had disappeared entirely, and all pains were about 25 per cent less. Before the injections he had had shooting pains every ten to fifteen minutes, which were now gone. The abdominal pain and burning on urination had become only a smarting sensation. The pains in the chest, right hip, knee and foot had disappeared.

The irritation of the twelfth dorsal and the first and second lumbar nerve roots by the needles used in the injections reproduced the entire nerve reflex caused by a ureteral pathologic condition except the bilaterality. Subsequently, when the procaine hydrochloride injected

into these nerves produced the concomitant anesthesia of the zones previously found to be hyperalgesic a twofold purpose had been accomplished.

The response of these structures to the injections requires further analysis. With reference to bilaterality, it may be said that although the injections were administered on the right side only, the reflex disappeared entirely on the left side also and remained considerably diminished on the day after the paravertebral injections. This evidence strongly suggests that the reflex on the side opposite the lesion may be due to spreading of the impulses from one side of the body to the other. The conclusion may be drawn, therefore, that a unilateral lesion may produce a contralateral reflex.

Three types of pain were felt: (1) muscular pain, which was dull and vague; (2) pain in an area the size of a silver dollar, corresponding to the point of maximum tenderness, and (3) radiating pain, which was sharp and well defined.

The following case is that of a patient presenting all of the ureteral hyperalgesic areas, who was given paravertebral injections by Dr. Sidney Immergut. Paravertebral injections were made separately into the left twelfth dorsal nerve on Aug. 12, 1934, into the left first lumbar nerve on August 14 and into the left second lumbar nerve on August 27. It was observed that after the injection into the first lumbar nerve root the hyperalgesia was considerably diminished, and the point of maximum tenderness dropped from 4 to 1 plus. After the injections into the twelfth dorsal and the second lumbar nerve roots, however, there was only a slight change.

The radiation of pain induced by faradic stimulation of the ureter by Ockerblad and Carlson [19] corresponds in many respects to the irritation of the spinal nerve roots in the paravertebral injections.

MECHANISM

The material presented in this report would be without point unless the mechanism of ureteral afferent nerve distribution were considered and hypotheses formulated concerning it. Such hypotheses can be based only on an analysis of the anatomicoclinical findings.

Cushing [20] after injecting cocaine into the ilioinguinal and iliohypogastric nerves noted that sensation disappeared in the oblique and transverse muscles. Lennander after division of the nerves in an incision through the sheath of the rectus muscle observed the mesial border of the incision to be without sensation. It is generally observed, further-

19. Ockerblad, N. F., and Carlson, N. E.: Ureteral Pain as Determined by Faradic Stimulation in Man, Proc. Soc. Exper. Biol. & Med. **36**:35 (Feb.) 1937.

20. Cushing, H.: The Employment of Local Anesthesia in the Radical Cure of Certain Cases of Hernia, with a Note upon the Nervous Anatomy of the Inguinal Region, Ann. Surg. **31**:1, 1900.

Tender points (*1*, *2*, *3*, *4* and *5*) in diseases of the renal pelvis and of the ureter. *A*, anterior view; *B*, posterior view. The point marked *M* indicates the point of maximum tenderness; that marked L_1, the first lumbar nerve.

more, that various tender points diminish and disappear as the ureteral pathologic condition clears up.

Head's work and the conclusions based on it were limited mainly to a study of tactile sensation. The regional anatomy, including a description of the nerves and muscles, was accorded scant consideration. The distribution of afferent sensation to the eleventh and the twelfth dorsal and the first lumbar nerve, as enunciated by Head, coincides with that generally accepted by the textbooks on anatomy. A careful analysis of Head's chapter on the ureter reveals the following observation: In case 32 (fig. 31) the shaded area represented the tenth, eleventh and twelfth dorsal nerves "in a case due to impaction of the stone in the ureter." Yet Head concluded by stating that diseases of the pelvis of the kidney and ureter are particularly associated with the eleventh and the twelfth dorsal and the first lumbar nerve. I agree that the hyperalgesia may extend to the area of the tenth dorsal nerve in the anterior abdominal wall. The conception that these impulses might be initiated in a narrower zone posteriorly and spread to a wider area anteriorly and laterally by way of an anastomotic network of nerves was apparently not considered by Head. Yet such a view was expressed by Sherrington,[21] who stated that "the shape of a segmental skin field . . . is somewhat broader near its ventral than its dorsal end."

In the case mentioned by Head the hyperalgesia was noted in the distribution of the tenth dorsal nerve. In the case previously reported, in which paravertebral injections were given, hyperalgesia was observed as high as the level of the seventh dorsal nerve. What is the anatomic basis for this remote transmission of nervous impulses?

In the work reported here, the peripheral distribution in the body wall will be considered as one of the routes apparently involved, the central one being omitted. An intersegmental anastomosis may take place in the following ways: in the dorsal axial muscles of the trunk, between adjoining intrathoracic intercostal nerves or in the anterior and the lateral abdominal muscles. In this paper the anastomosis in the anterior and lateral parts of the abdominal wall will be described.

The iliohypogastric nerve has been observed occasionally to send filaments to the rectus abdominis muscle (Rugé; Bardeen; Eisler;[22] Hovelacque), and the twelfth intercostal nerve reaches the muscle in 110 of 112 cases (Bardeen). According to Davies and his associates,[23]

21. Sherrington, C. S.: Experiments in the Examination of the Peripheral Distribution of the Fibers of the Posterior Roots of Some Spinal Nerves, Proc. Roy. Soc., London **52**:333, 1892-1893.

22. Eisler, P.: Die Muskeln des Stammes, in von Bardeleben, K.: Handbuch der Anatomie des Menschen, Jena, Gustav Fischer, 1912.

23. Davies, F.; Gladstone, R. J., and Stibbe, E. P.: The Anatomy of the Intercostal Nerves, J. Anat. **66**:323 (April) 1932.

any nerve in the region of the rectus abdominis muscle contains fibers from at least two, and sometimes three, intercostal nerves. In addition, Hovelacque mentioned that in their abdominal portion the nerves anastomose with each other, the most richly developed anastomosis being at the level of the lower nerves to form a veritable plexus.

In addition, in 8 dissections of the iliohypogastric nerve I have demonstrated its anastomosis with the eleventh dorsal nerve twice, with the twelfth dorsal nerve five times and with the ilioinguinal nerve three times. Cruveilhier also observed a frequent anastomosis with the twelfth intercostal nerve. In addition, I have demonstrated that a vast plexus formation composed of branches of the lower intercostal nerves spreads out over the trunk and branches of the deep circumflex iliac artery. The branches of this artery may carry the nerve fibers to higher levels and aid in the further anastomosis of these nerves. It can readily be seen that an impulse traveling along the course of any nerve or group of these nerves will be transmitted to those nerves and arteries which intercommunicate by way of the anastomosis and the plexus formation with adjoining segments.

Gregoire stated that section of a single intercostal nerve seems to be without effect on the musculature of the abdomen but that it is necessary to cut at least three nerves in order that paralytic manifestations may appear.

One should not, therefore, overlook that allowance should be made for the normal individual variation in the composition and course of the lower intercostal nerves, including the iliohypogastric and the ilioinguinal.

Besides this quantitative involvement, one must consider the qualitative element, the intensity of the pain. I am of the opinion that the first lumbar nerve responds with the maximum sensitivity. This opinion is based on the following observations: Patients with ureteral calculi complain of pains a little above the inguinal ligament, which radiate to the pubis, testis, vulva or thigh. Objectively, there is corresponding hyperalgesia along the course of the first lumbar nerve. The point of maximum tenderness coincides with the emergence of the iliohypogastric (first lumbar) nerve from the internal oblique muscle. In addition, the hyperalgesia of the second lumbar nerve is represented mainly in the femoral triangle. Spread beyond this is by way of the lumbosacral plexus. Involvement of the twelfth dorsal nerve is shown by the inguinal band of hyperalgesia. Extension cephalad to this takes place as previously mentioned. Frequency of micturition has been alleviated, with no detrimental effect, by removal of the large white ramus coming from the first lumbar nerve to join the sympathetic trunk (Royle).[24]

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24. Royle, N. D.: Treatment of Spastic Paralysis by Sympathetic Ramisection, Surg., Gynec. & Obst. **39**:716, 1924.

According to Libman,[25] there are sensitive and hyposensitive persons, and the degree of sensitivity manifested is modified by whether the patients belong to one or the other category. Another variable factor is the severity of the morbid process. These two considerations must be recognized in an attempt to evaluate clinically the intensity and distribution of pain.

The following hypotheses may therefore be submitted:

1. The minimal and unilateral reflex is confined mainly to the twelfth dorsal and the first and the second lumbar spinal nerve. In the peripheral distribution, diffusion to outlying zones takes place by transmission of the impulses to adjoining nerves by way of nerve anastomoses and plexus formation.

2. In the minimal and bilateral reflex the invasion takes place additionally in the same spinal segment and on the contralateral side.

3. In the maximal reflex there is diffusion beyond its localized confines into the surrounding segments, that is, the chest, the upper part of the abdomen and the lower extremities, either unilaterally or bilaterally.

4. In cases in which bilaterality is present, the contralateral reflex is less intense than the reflex on the involved side. The greater the intensity of the stimulus on the affected side, the more frequently the bilateral reflex is present.

The extent of the entire reflex depends on the intensity of the impulse and the threshold of resistance.

The ureteral reflex has been observed in cases of gastric or duodenal ulcer, disease of the gallbladder and coronary attacks.

In conclusion, it may be stated that the initiation of the impulse is by way of the autonomic nervous system at the site of the stimulation, in the pelvis of the kidney or in the ureter, and that the impulse is transmitted afferently by peripheral distribution to the body wall by way of the twelfth dorsal and the first and the second lumbar spinal nerve. Diffusion may take place into higher and lower segments, either unilaterally or bilaterally by way of nerve anastomoses.

SUMMARY AND CONCLUSIONS

The relations of the iliohypogastric, ilioinguinal and genitofemoral nerves to the muscles of the trunk are reviewed and additional personal observations recorded. Plexus formation and anastomosis of the iliohypogastric nerve with adjoining spinal nerves and with the deep circumflex iliac artery were observed. A variation was noted in the point of emergence of the iliohypogastric nerve from the internal

25. Libman, E.: Observations on Individual Sensitiveness to Pain, J. A. M. A. **102**:335 (Feb. 3) 1934.

oblique muscle. The aponeurotic intervals of the external and internal oblique and transverse abdominis muscles were found to vary in width.

Muscle spasm and tenderness were observed over the external oblique and the rectus abdominis muscle, and to a less extent over the intervening fascial space.

The upper limits of hyperalgesia were found to extend to the eighth or ninth dorsal spinal nerve or higher and the lower limits to the second lumbar nerve.

Five points of deep hyperalgesia were observed:

1. At the first lumbar nerve, near the spine of the vertebra.
2. In the posterior part of the iliac crest.
3. One inch (2.5 cm.) mesial to and on a level with the anterior superior iliac spine (point of maximum tenderness). Normal anatomic variations were noted.
4. Above and lateral to the crest of the pubis.
5. Within the femoral triangle.

These tender points were frequently found on the side opposite the morbid process. In 14 of 17 cases, or 82.4 per cent, the lesions were localized by means of these points.

Joint pains which occurred during an attack of calculus of the ureter disappeared on alleviation of the attack.

"Tenderness along the course of the ureter" was found to correspond with tenderness along the lateral edge of the rectus abdominis muscle.

The contralateral reflex associated with a unilateral lesion was observed in 29.4 per cent of cases of calculus of the ureter. This is known as the "renorenal reflex."

A patient with calculus of the right ureter and bilateral physical findings received paravertebral injections of 2 per cent procaine hydrochloride into the twelfth dorsal and the first and the second lumbar spinal nerve root on the right side. A study was made of the tender points, areas and symptoms occurring bilaterally before and after the injections.

The mechanism of distribution of the afferent nerves, particularly the peripheral, was studied from the anatomic and from the clinical point of view. The involvement of the twelfth dorsal and the first and the second lumbar nerve in diseases of the ureter was analyzed.

Hypotheses relative to the mechanism of the ureteral reflex are formulated. Consideration is given to: (1) the minimal and unilateral ureteral reflex; (2) the minimal and bilateral ureteral reflex; (3) the maximal ureteral reflex, and (4) the contralateral (bilateral) ureteral reflex.

MORBIDITY CAUSED BY OPERATIVE COMPLICATIONS

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In considering the value of any operative procedure, critical analysis of several factors is necessary. The mortality of the operation must be compared with the mortality of the disease for which it is performed, and the complications of the operation must be compared with the complications of the untreated disease. In a review of any series of operations it may be seen that both fatal and nonfatal complications arise, which are not inherent in the type of operation but may be sequelae of any surgical procedure. These include wound infections and pulmonary lesions. It is this group of postoperative complications that I wish to discuss in this paper. It has been said that all surgical procedures, no matter how simple, are attended by some risk of complications. As surgical science advances, the number of such complications will be reduced toward the minimum. During this evolutionary process, however, many prophylactic and therapeutic measures have been and will be suggested. These must be carefully weighed, the good ones being retained and the poor ones discarded.

Wound infections probably constitute one of the most common types of postoperative complication. In a recent survey of seventeen surgical teaching clinics,[1] I have found that there are almost as many methods in practice for the preparation of the operative field and the preservation of asepsis in the operating room. This might mean that all the methods are perfect, that none are perfect or that it is not known which is the best. The last is probably nearest the truth. The reason for this lack of knowledge is that studies of wound infection have been made, to a large extent, in vitro rather than in vivo. True statistical analyses have rarely if ever been made, but they are necessary to give proper weight to the many variables involved.

A similar problem confronted the obstetricians, who attempted to study the effects of their aseptic methods. For this purpose several of the local obstetric societies appointed commissions, who made a detailed

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1. Beck, W. C.: Preparation of the Operative Field: Report of a Survey of Seventeen Surgical Teaching Clinics, Arch. Surg. **33**:876 (Nov.) 1936.

study of the problem. They found that the first prerequisite was to define what constitutes morbidity in a given case and then to make this definition hard and inflexible for the purpose of comparative study. Not all of the various commissions active throughout the United States have adopted exactly the same definition, yet the material of each group is sufficiently large to make possible certain valuable generalizations.[2] Substandard methods of treatment have been recognized, and a definite reduction in maternal morbidity has been rendered possible. The problems of general surgery, because of their variety and complexity, are not so easily applicable to comparative study as are those of obstetrics. In the search for a method of study and statistical evaluation, however, the following analysis was carried out.

METHOD AND MATERIAL

In reviewing a rather large series of old charts, it was found that many of the complications which had evidently arisen were poorly recorded. This was true

TABLE 1.—*Operative Complications*

Total number of cases with uncomplicated convalescence	332 (73.8%)
Total number of cases with complicated convalescence	118 (26.2%)
Total number without listed complications but with abnormal prolongation of fever	15 (3.3%)
Total number with complications but without abnormal prolongation of fever	6 (1.3%)

Report on 450 cases (thyroidectomy, 70 cases; herniorrhaphy, 145 cases; laparotomy, 175 cases; miscellaneous [mastectomy, removal of tumors, sympathectomy, etc.], 60 cases).

not only of the records in the private hospital but of those in the teaching clinics and charity hospitals. It was therefore necessary to work forward rather than backward in studying the cases. To do this adequately, I enlisted the services of the senior surgical residents in the charity hospitals. They were given a "complication sheet" to fill out for every case (table 1). This was done at the time of discharge of the patient from the institution. The records included a report of any preoperative complication, of the character and severity of the operation and of the postoperative complications. The type and rate of the pulse were recorded, and also the postoperative duration of tachycardia. The height of the postoperative temperature and the duration of any febrile reaction were recorded. In a small series of cases, total and differential counts of the leukocytes were carried out and correlated with the postoperative course. In another small series, determinations of the sedimentation rate were carried out during the postoperative period and correlated with the clinical course. Whenever there was doubt about the presence of complications, the interns' and nurses' notes were carefully reviewed for any possible clues. The latter proved illuminating in several cases in which it was recorded that the patient was coughing a great deal and expectorating large amounts of yellow mucus, although there was no mention in the intern's progress notes of any pulmonary complication. In such cases, either the record was discarded as incomplete or the attending surgeon was questioned.

2. Cornell, E., chairman of the Committee on Maternal Welfare Statistics, Chicago Gynecological Society: Personal communication to the author.

Whenever possible, some type of definition was coined for the different complications. Claude Beck's classification of wound infections was used so that an accurate analysis of the course of wound healing could be obtained. Only the obvious neurologic and psychiatric complications were listed unless consultation notes were available. The same held true for cardiac complications, so that possibly some of these were missed. Pulmonary complications were classed as bronchitis, bronchopneumonia, lobar pneumonia, massive collapse of the lung, atelectatic pneumonitis and embolic phenomena. Complications in the urinary tract were noted only when they were productive of fever and caused obvious changes in the urine. For example, retention of urine demanding catheterization was not recorded. The recording of gastrointestinal complications was carried out only when such complications were of significant importance. Thus, postoperative "gas pains" do not appear in the records unless they were significant of inflammatory or obstructive ileus. Minor cutaneous manifestations, such as "sheet rash," were not recorded. Serious cutaneous conditions, e. g., decubitus ulcers, were recorded.

For the purposes of this study, only operations performed in an uninfected field or those in which the danger of infection was presumably minimal were used. The inclusion of other operations would have complicated the problem too

TABLE 2.—*Wound Complications*

Number of cases studied		450
Number of cases with wound complications		56 (12.4%)
Group I	1 case	(Secondary hemorrhage)
Group II	13 cases	(Sterile hematoma)
Group III	9 cases	(Infected hematoma)
Group IV	12 cases	(Mild infection)
Group V	17 cases	(Moderate infection)
Group VI	2 cases	(Serious infection)
Group VII	1 case	(Evisceration)
Group VIII	1 case	(Necrosis of edges)
Group IX	None	(Sinus or fistula)

much. For example, interval appendectomies and cholecystectomies for chronic cholecystitis were included, while similar operations for acute appendicitis and acute cholecystitis were not included. All of these should belong to group A according to Beck's classification (table 8).

The results of this investigation are not to be considered as evaluations of any standard or specific procedure. The operations were carried out in three different hospitals with the use of different technics and on patients of different classes. Two of the hospitals were charity institutions, and one was private. The operations were not all carried out by the same surgeons. The preparation of the operative field differed markedly in the three institutions and even in the same hospital with different operators. To obtain accurate, comparable statistics, certain definite rules must be observed, which will be formulated later in this article. It must be remembered that the statistics compiled here represent a composite picture.

In this series 450 cases were studied. As will be seen from table 1, the operations were divided into four groups: thyroidectomies, herniorrhaphies, laparotomies and miscellaneous procedures. The first two groups consisted of operations which were performed in tissue absolutely uninfected, while the latter two groups contained some in fields which might be considered as potentially infected, for instance, appendectomies in the interval stage. No case of the invasion of a grossly contaminated field was included in the series.

The first object of the study was to find some criterion for the presence of a complication of the normal postoperative convalescence. For 15 patients, daily leukocyte counts were carried out during the first six postoperative days. One of the patients had severe bronchitis, and 2 had wound infections of moderate degree. The leukocyte counts of these 3 patients with complications were slightly higher than those of the normal patients. Eight of the patients, however, had elevated leukocyte counts for all of the period studied, and the difference in this respect between the complicated and the uncomplicated conditions was not found to be sufficient to warrant carrying out this procedure as a routine. In another series, of 10 patients, the sedimentation rate was studied daily for a similar period. In this series there were 1 patient who had thrombophlebitis and 1 who had a moderate wound infection. All of these patients had accelerated sedimentation rates, but the rates for the patients with postoperative complications did not differ appreciably from those for patients with an uneventful convalescence.

It was noted that nearly all of the patients studied had a postoperative rise in temperature. The degree of the rise did not appear to be correlated with the severity of the operation or with the complication in the postoperative course. The status of the patient at the time of the operation did not appear to have any bearing on the height of the febrile reaction. The fever usually subsided by the third or fourth postoperative day. However, it was noted that when a complication occurred the temperature almost invariably remained above 99.6 F. after the fourth postoperative day or rose above this level during the postoperative course. Taking special note of this fact, I reviewed the histories of the patients who had been discharged as without complications and who had had a temperature above 99.6 F. after the fourth day, and in most instances found an explanation. One patient was discharged from the hospital, after a supposedly normal convalescence, with a temperature of 100 F. He returned to the hospital eight days after discharge with a deep subfascial collection of pus which required evacuation. A second patient was returned to the referring physician, who reported evacuating several cubic centimeters of serum from the wound two weeks after discharge. When the case history was reviewed it was found that the patient had had a persistent febrile reaction during the postoperative course. As will be seen from table 1, in only 3.3 per cent of the cases in which there was a temperature of over 99.6 F. after the fourth day could no cause be found. Some of these cases were in the earlier group, studied before we became aware of this phenomenon. In only 1.6 per cent of the cases was there a complication unattended by this rise in temperature. In none of the latter cases were severe complications present. In 1 of them there was a massive collapse of the lung, which was immediately reduced.

The pulse rate did not appear to be significant. Many patients had elevations of pulse rate without any complication, while others, with severe complications, had little or no elevation in the rate.

PREOPERATIVE COMPLICATIONS OR ASSOCIATED PATHOLOGIC LESIONS

It will be noted from tables 3 to 6 that the percentage of preoperative complications is very high. There are several reasons for this. Certain lesions were termed complications although they were a part of the disease for which the operation was performed. For example, thyrotoxic heart disease was listed as a complication of hyperthyroidism. Similarly, hypertension was listed as a complication in 2 cases in which splanchnicectomy was performed for its relief. It is undoubtedly true

TABLE 3.—*Complications Following Thyroidectomy (70 Cases)*

	Number	Percentage
Preoperative associated pathologic lesions	40	57
Thyrotoxic heart disease	36	51.4
Hypertension	2	2.8
Renal damage	2	2
Mild psychosis (coexistent with thyrotoxic heart)	1	1.4
Postoperative complications	11	15.7
Wound infection (group II, 2; group III, 1; group V, 1)	4	5.9
Thyroid crisis (mild)	2	2.8
Pulmonary complications	4	5.9
Auricular fibrillation	1	1.4

TABLE 4.—*Complications Following Herniorrhaphy (145 Cases)*

	Number	Percentage
Preoperative complications	4	2.6
Pulmonary tuberculosis	2	1.3
Syphilis	2	1.3
Postoperative complications	22	15.2
Wound complications (group II, 3; group III, 2; group IV, 1; group V, 9)	15	10.3
Pulmonary complications	4	2.6
Urinary complications	2	1.3
Abscess on arm	1	0.75

TABLE 5.—*Complications in Laparotomies (175 Cases)*

	Number	Percentage of Incidence	Percentage of Complications
Preoperative complications	26	14.8	
Debility and cachexia	12	6.8	46.9
Severe secondary anemia	5	2.7	19.3
Dehydration	5	2.7	19.3
Cardiac lesions	2	1.1	9
Psychosis	1	0.5	4.5
Previous nephrectomy for tuberculosis	1	0.5	4.5
Postoperative complications	67	38.2	
Wound infection (group I, 1; group II, 4; group III, 4; group IV, 9; group V, 7; group VI, 1; group VII, 1)	27	15.4	40.3
Pulmonary complications	15	8.5	22.4
Urinary complications	10	5.6	15
Inflammatory ileus	5	2.8	7.5
Cardiac complications	3	1.7	4.5
Thrombophlebitis	2	0.9	2.8
Furuncles and carbuncles	2	0.9	2.8
Decubitus ulcers	2	0.9	2.8
Subphrenic abscess	1	0.45	1.4

TABLE 6.—*Complications in Cases of Miscellaneous Operations (60 Cases) (Mastectomy, Removal of Tumors, Sympathectomy, Etc.)*

	Number	Percentage of Incidence	Percentage of Complications
Preoperative complications	8	13.3	
Hypertension	3	5	37.5
Anemia	3	5	37.5
Cachexia	1	1.7	12.8
Diabetes	1	1.7	12.8
Pulmonary tuberculosis	1	1.7	12.8
Postoperative complications	18	30	
Wound infections (group II, 4; group III, 2; group IV, 2; group VI, 1; group VIII, 1)	10	16.6	55.5
Pulmonary complications	5	8.3	27.9
Cystitis	1	1.6	5.5
Gastroenteritis	1	1.6	5.5
Paronychia	1	1.6	5.5

that only too often certain associated lesions remain unnoticed before the operation and are brought to light during the convalescence. This may be because of incomplete examination of the patient. On the other hand, certain of these complications are recognized and are not especially considered until they are aggravated or altered by the operative procedure. Thus, in 1 of the cases in which laparotomy (cholecystectomy) was done, a notation appeared in the report of the physical examination that the heart was enlarged and that there was a loud, blowing systolic murmur. On the third postoperative day the patient had an irregular pulse and an auricular fibrillation. No medical consultation had been held in this case, and it is possible, as the operation was not urgent, that medical care might have prevented this. Routine examination of the urine of surgical patients not infrequently brings to light diabetes. The case is then almost invariably considered in a special light, and surgical intervention is delayed for the proper care of the complication. Other preoperative complications should have the benefit of similar consideration.

TABLE 7.—*Postoperative Days in Hospital*

Uncomplicated thyroidectomies	3.92 days*
Complicated thyroidectomies	6.84 days
Uncomplicated herniorrhaphies	10.2 days
Complicated herniorrhaphies	15.8 days

* Patients remaining in the hospital for social service disposal have been excluded.

Of the 450 cases studied, some preoperative complication was present in 78, or 15.3 per cent. As may be observed from table 2, 57 per cent of the patients on whom thyroidectomy was performed had preoperative complications. There were postoperative complications in 11 cases, in 8 of which there had been preoperative complications. This is as would be expected, i. e., a patient in whose cases there are preoperative complications will have a more complicated postoperative course. Nevertheless, one should glean from such figures that, as precautions are taken in the treatment of preoperative complication, the frequency of postoperative complications will be reduced.

POSTOPERATIVE COMPLICATIONS

From table 1 it will be observed that of the 450 patients 332, or 73.8 per cent, had an uneventful convalescence, whereas 118, or 26.2 per cent, had some complication during the postoperative course. It is interesting that in no case was more than one complication noted. This may be due to lack of observation on the part of the person filling out the report but is more probably due to the fact that the presenting complication overshadowed the secondary one. There were 5 deaths in this series,

1 from a virulent infection, 2 from pulmonary embolism, 1 following an exploratory laparotomy for an inoperable carcinoma and 1 following an evisceration. This rather low mortality rate is probably due to the type of operations which were selected for this study ("clean" operations) and to the small number in the series.

It will be observed that two important complications have not been noted, surgical shock and "gas pains." The former probably did not occur, since the operation in the groups studied is rarely known to produce shock, although several gastric resections were included. Gas pains could not be included, as they are entirely subjective. Inflammatory ileus was observed in 5 patients. These had distention, silent abdomens and temperatures above 99.6 F. after the fourth day.

The largest group of postoperative complications is composed of complications related to the wound. In the series of 450 operations

TABLE 8.—*Classification of Wound Healing (Claude Beck *)*

A.	Clean surgical wounds
B.	Potentially infected surgical wounds
C.	Wounds in a grossly contaminated field
Subclassification:	
0.	Healing by primary intention
I.	Secondary hemorrhage
II.	Sterile hematoma
III.	Infected hematoma
IV.	Mild wound infections, such as stitch abscesses, "seromas," erythematous wound edges
V.	Moderate infections
VI.	Serious spreading infections
VII.	Eviscerations
VIII.	Necrosis of the edges, as in plastic operation, subcutaneous dissections, etc.
IX.	Persistent sinus or fistula

* Beck, C.: Personal communication to the author.

there were 56 wound complications (table 8); i. e., after 12.4 per cent of the wounds showed abnormal healing (not all these wounds were infected). This is a very high figure, comparing unfavorably with the published statistics (with the exception of those published by Meleney [3] in 1934). We believe that there are several reasons for this. The most important, in our opinion, is that the diagnosis of a complication referable to the wound was made after careful study of the wound rather than by study of the chart after the patient had left the hospital. All of the complications which occurred in the wounds were included, not only those which caused frank suppuration. Most of the patients were operated on in amphitheaters in the presence of students and visitors. Many of the visitors in the amphitheaters did not wear caps or masks,

3. Meleney, F. L.: Infection in Clean Operative Wounds: A Nine-Year Study, Surg., Gynec. & Obst. **60**:264, 1935.

but a glass shield [4] in one of the hospitals separated them from the operation. In the other hospital there is no special shield for the prevention of droplet infection. The preparation of the operative field in the three institutions differed. In the first, the skin was prepared with a 6 per cent tincture of iodine or with the compound tincture, the excess being removed with alcohol. In the second, the skin was washed for ten minutes with sterile soft soap U. S. P. (green soap) and sterile water; this was followed by application of the compound solution of mercuric chloride described by Vaichulis and Arnold.[5] In the third institution, the skin was washed with soap and water for five minutes, and mecresin [5a] was then applied. A comparative study will be presented in a subsequent report, for reasons outlined under statistical comparisons.

In this series the wound infections were incompletely studied from the bacteriologic standpoint. In the 2 cases of serious and spreading infection a hemolytic streptococcus was recovered. Cultures were obtained in only 2 of the cases of infected hematoma; in 1 of these Staphylococcus albus was recovered, while in the other a staphylococcus of the hemolytic type was found on culture.

It will be noted from table 7 that the largest group of wound complications resulted from hematomas in the wound. I have noted that when the edges of the wound are slightly raised and slightly reddened a hypodermic needle inserted into the wound will usually aspirate a small or moderate amount of old blood or of blood-stained purulent material. I therefore came to the belief that these were small hematomas rather than infections. The one evisceration occurred after an exploratory laparotomy in a debilitated and cachectic patient with an inoperable carcinoma of the stomach. There were no evidences of wound healing in this patient, and the wound was infected. The evisceration took place on the eighth postoperative day, and the patient died.

The next most common complication was pulmonary. As will be observed from table 9, most of the ailments in the group were classified as bronchitis. It was difficult to determine how many manifestations were necessary to justify a diagnosis of bronchitis, but it was thought that a significant febrile reaction associated with cough and chest rales was sufficient. Whether or not this minor bronchitis represented small areas of atelectasis is not in the province of this discussion. There were 8

4. Some question as to the efficacy of the glass shield might be raised, according to the researches of Wells, F.: Papers on Air Borne Infection, Cambridge, Mass., Harvard University Press, 1937.

5. Vaichulis, J. A., and Arnold, L.: A New Bacteriocide, Surg., Gynec. & Obst. **61**:333, 1935.

5a. Mecresin (Upjohn) is composed of alcohol, 50 per cent; secondary amyl tricresols, 0.1 per cent; orthohydroxylphenyl mercuric chloride, 0.1 per cent, and acetone, 10 per cent.

lesions definitely classified as atelectatic. Further study of this question is in order. Correlation with the modes of anesthesia was not carried out in this series.

In the entire series there were 13 patients, or 2.8 per cent, with complications referable to the urinary tract. There was usually mild cystitis, although there was 1 instance of violent cystopyelitis which resisted therapy. In reviewing the charts it was found that only 6 of the patients had had retention of urine requiring catheterization. The complication arose most frequently in young persons.

Thrombophlebitis of the femoral vein occurred in only 2 persons in the entire series. Both of these patients had varicose veins, and 1 of them had received several injection treatments of the veins before the operation. No definite predisposing factors other than this could be ascertained. In 1 of the patients the thrombophlebitis was mild and the patient's stay in the hospital was not greatly prolonged, while for the other patient hospitalization was prolonged to six weeks.

TABLE 9.—*Pulmonary Complications*

Number of cases studied	450	
Number of pulmonary complications	28	(6.2%)
Classed as bronchitis or tracheobronchitis	12	
Classed as atelectasis or atelectatic pneumonitis	8	
Classed as lobar pneumonia	1	
Classed as bronchopneumonia	4	
Pulmonary embolism	2	
Pulmonary infarction	1	

The other complications were so inconstant that discussion of them is scarcely indicated.

DURATION OF HOSPITALIZATION

The economic factor of operative complications is not inconsiderable. It is naturally important to determine how much longer the patients with complications remained in the hospital than those who had a normal convalescence. Today, when hospital insurance is becoming accepted, this factor will have to be taken into serious consideration. It also may be taken as an index of the severity of the complications. In this series only the thyroidectomies and herniorrhaphies are capable of comparison. As is seen in table 6, the average stay in the hospital for the patients in whose cases complications followed thyroidectomy was two and ninety-two hundredths days longer than for those with normal convalescence. For the herniorrhaphies the difference was five and five tenths days. This means that the patients on whom thyroidectomy was performed spent thirty-two and twelve-hundredths extra days in the hospital because of a complication, while those on whom herniorrhaphy was performed spent one hundred and twenty-three and two-tenths extra days

in the hospital. This figure would probably be much higher for a series of private patients, as such patients are often kept in the hospital until all evidence of the complication has disappeared. It is also worth noting that the complications following thyroidectomies and herniorrhaphies were mild and innocuous in comparison with those following laparotomies and miscellaneous operations.

COMMENT

It will be noted from the foregoing section that only the complications which follow surgical operations in general have been discussed. These are the ones which are often neglected and viewed with equanimity until some minor complication develops into a major one. When this occurs there is usually a general change in technic, followed by another period of quiescence until the next accident. I believe that surgeons should keep their technics in a constant flux, discarding the poorer methods for the better. This is possible only with comparable statistics. Many factors enter into the pathogenesis of the aforementioned complications. To evaluate any one of them all of the others must be kept at an absolute or relative value. For instance, in evaluating the comparative merits of silk and catgut for suturing infected wounds, the same type of patient must be used in all instances; the same surgeon must do the operating, preferably with the same team; the same operation must be done; the same preparation of the operative field must be carried out in the same operating room; the season of year should be the same, and the same draping and sterilization technic must be used. Above all, the series must be sufficiently large to obviate minor differences not noted. Therefore, this series is not a fit subject for comparison, as it is heterogeneous rather than homogeneous. It is reported, however, as possibly forming a base line from which further statistical study may proceed.

In reviewing the practical lessons learned from this study one finds that probably the most important is that an explanation can usually be found for a temperature which remains over 99.6 F. for more than four days. If one is alert for this sign one will be able to "pick up" far more of the complications which beset the surgical patient. If the complications are faithfully recorded, a cause and a cure for some of them will undoubtedly be found.

It is also found that no single definition of a "wound complication" is possible. It is impossible to record that a wound heals by primary or secondary intention or to classify wounds by any such simple method. Rather, it is necessary to complicate the classification and study the wound healing process by analysis, as is indicated in table 9.

Further, this study shows that complications may be studied by a quantitative as well as qualitative method. This can be done by the

determination of a normal duration of stay in the hospital. Patients who remain beyond this time *because of a complication* can be classified according to the period of time that they are hospitalized. Patients remaining in the hospital for study or for social or economic reasons cannot be included.

These criteria are more or less arbitrary. It would probably be best if the surgeons would emulate the obstetricians and through some surgical organization devise definitions of the various types of complicated convalescence and complicated wound healing. This would certainly be attended by some error, but in general the error would disappear with a large series. In this way accurate evaluations of the technics now in use would be possible.

SUMMARY AND CONCLUSIONS

1. It is absolutely necessary to use an accurate statistical method in evaluating the procedures used for the prevention and treatment of surgical complications.

2. Such statistics can be arrived at by securing arbitrary criteria for the presence of complications. It has been observed that a temperature of 99.6 F. for four or more days accompanies all but a small percentage of complications. In analyzing the value of any method, all other factors which may influence the result must be kept constant.

3. A series of 450 major surgical procedures has been analyzed from the standpoint of complications. This review has been made to demonstrate the feasibility of such a study rather than to offer comparable statistics.

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SIXTY-NINTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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LOS ANGELES

CONGENITAL DEFORMITIES

Osteopsathyrosis.—Lippert [1] reports 3 cases of osteogenesis imperfecta. His patients were related, and in the same family there were 9 members with fragile bones. There was no biochemical evidence to show that the disease was related to pathologic absorption or retention of calcium or phosphorous. The treatment of the fracture was the same as that for normal persons. Rapid healing with callus formation was the rule. Administration of various drugs, vitamins and extracts did not affect the disease.

Humeral Varus.—Burman [2] reports in detail a case of this rare condition. He states that only 8 cases have been recorded in the literature. The roentgen picture in his case was typical. The head of the humerus was in a varus position, so that the angle of inclination, which is normally 130 to 158 degrees, was reduced to less than 50 degrees. The tuberosities were elevated; the greater tuberosity was placed at a higher level than the head of the humerus, whereas normally it is about 6 mm. lower. The epiphysial line was vertically rather

This report is based on a review of 147 papers selected from 224 titles relating to orthopedic surgery and appearing in the medical literature approximately between Nov. 1, 1938 and March 1, 1939.

1. Lippert, K. M.: Surgery **4**:762, 1938.

2. Burman, S. M.: Am. J. Roentgenol. **40**:682, 1938.

than horizontally placed. In such a case fusion may be premature, but is uncertain whether the rate of growth is greater in the upper or lower parts of the epiphysial line. This condition is due to an epiphysial injury sustained at birth or early in life. The patient in the case reported by Burman was born by breech delivery with a known injury to the arm on the affected side. The uncommonness of the disease is explained by the following facts: First, it must be produced at birth by injury through breech delivery; second, it must injure the medial part of the epiphysial line so that its rate of growth is best at the outer part, and third, it must have a long enough period for its development. Treatment should consist of osteotomy "to correct the humerus varus of the head." In addition, fusion of the superior part of the epiphysial line may be considered in each particular case.

DEVELOPMENTAL DISEASE

Treatment of Essential Coxa Vara of Adolescents.—Van Ness [3] discusses under this heading the treatment of epiphysiolysis of the upper femoral epiphysis in 17 patients ranging in age from 11 to 17 years. There were 12 boys and 5 girls. Closed reduction was found to be unsatisfactory, the reposition being more apparent than real. Redressement alone was carried out for 8 patients. There was only 1 good result. In 2 patients ankylosis developed. In the remaining 5 there was limitation of motion. One patient, with early involvement, was treated only by abolition of weight bearing and the use of crutches, with a good result. One patient was treated with a traction caliper. This patient showed moderate limitation of flexion and rotation. Four patients were treated by osteosynthesis of the upper femoral epiphysis with a Smith-Petersen nail. The results were excellent in 3 cases and good in 1. The author advises this method in all cases in which there is not much displacement of the upper femoral epiphysis. When there is much upward displacement of the greater trochanter a transtrochanteric osteotomy to produce relative coxa valga is recommended. This method has been used for 3 patients with excellent results and is preferred to an intra-articular operation.

Epiphysiolysis in Adolescence.—Pomeranz' [4] study is based on knowledge gained from a review of approximately 200 cases of slipped femoral epiphysis. He states the belief that no "preslipping stage" of the disease exists because when suggestive clinical symptoms are present there are always distinct roentgen features which indicate that slipping is taking place. In the early stages there are absence of the projecting

3. Van Ness, C. P.: Bull. Soc. belge d'orthop. **11**:6, 1939.

4. Pomeranz, M. M.: Am. J. Roentgenol. **40**:580, 1938.

"hump" of the capital epiphysis, increased width of the epiphysial line and subchondral resorption of the femoral neck. In the moderately advanced stages there is downward, inward and backward rotation of the femoral epiphysis with the femoral neck anteverted. In some of the treated and all of the untreated patients, union of the head and neck in the slipped position led to prominent changes which could be recognized later in life. Osteoarthritis is severe in cases of advanced involvement and may lead to permanent ankylosis of the hip. By experiments utilizing the hip of the monkey it was found that the increase in width of the epiphysial line is in reality produced by progressive anterior rotation of the femoral neck. The concentric defects seen in the roentgenograms represent the concurrent margins of the femoral neck and the epiphysis.

OSTEOMYELITIS

Acute Hematogenous Osteomyelitis.—Key [5] divides patients with acute hematogenous osteomyelitis into four groups: 1. Patients with mild infections who are not acutely ill. Early but not emergency drainage is advocated. 2. Severely ill patients with spreading infection but in good general condition. Immediate operation is advised unless the patient is under 3 years of age. 3. Severely ill patients in generally poor condition. Delay is advised until the general condition and the resistance can be improved. The interval, however, is a matter of hours rather than of days. 4. Patients in whom the infection has broken through the bone and whose acute illness is subsiding. Operation should be performed soon on persons in this group, but the condition does not constitute an emergency.

The reasons for these conclusions are clearly given and are based partly on the following findings: (*a*) under 2 years of age the organisms may be streptococci instead of staphylococci; (*b*) septicemia, if present, is due to infection in the osseous focus and not vice versa, and (*c*) mechanical localization of infection in the bone tissue is different. The conclusions are: 1. Early diagnosis is important, and each case should be considered individually on the principle that a deep abscess should be drained as early as possible. 2. Not every patient requires immediate operation, but every patient presents an acute surgical emergency. 3. Early and adequate drainage in cases of acute osteomyelitis is the most effective means of preventing chronic osteomyelitis.

Osteomyelitis During the Period of Growth.—Osteomyelitis in children is divided by Feure [6] into three phases: the entry of the organism,

5. Key, J. A.: Rational Treatment of Acute Hematogenous Osteomyelitis, J. A. M. A. **111**:2163 (Dec. 10) 1938.

6. Feure, M.: Arch. de méd. d. enf. **41**:695, 1938.

the transportation of the organism and the development of a focus of infection in the bone. The author distinguishes five types of osteomyelitis: 1. Primary septicemic osteomyelitis. The initial blood culture yields bacteria, and there occurs a secondary infectious focus in bone. 2. Secondary septicemic osteomyelitis, in which the osseous focus is the source of the organism in the blood stream. 3. Pyemic osteomyelitis, with the formation of secondary foci in bone or in the viscera. 4. Acute frank osteomyelitis, without evidence of septicemia. 5. Resolving osteomyelitis, healing spontaneously without formation of pus.

There are two theories of the mechanism of acute osteomyelitis. According to Lannelongue's theory the bacteria localize in the metaphysis, where the circulation of the bone is most active during growth. Here the process involves simultaneously the marrow and the bone tissue, with secondary necrosis and sequestrum formation. According to Wilensky's theory the osseous necrosis depends directly on a septic embolus which obliterates one of the nutrient arteries of the bone. Systematic abstention from operation is rarely sufficient. Simple incision of the subperiosteal abscess often suffices for infants and young children. Opening the bone by drilling or by removal of a window is indicated in many cases. Resection of the bone is dangerous because of the possibility of failure of regeneration. Postoperative care should consist of good immobilization, often by plaster, with infrequent dressings.

Acute Osteomyelitis in Adults.—The records of 9 cases of acute osteomyelitis in adults are reviewed by Zadek.[7] Trauma and previous infection were noted in 3 cases. In adults the disease is slow and insidious but of gradually increasing intensity. The destruction is principally central and periosteal and is more likely to start in the shaft than in the metaphysis, since the blood supply of the bone is more evenly distributed in adults. The route of spread is chiefly through the central canal, and the development of a subperiosteal abscess is unlikely, owing to the firm adherence of periosteum to bone in adults. The shaft of the femur is most often involved. There may result a local area of periosteal bone production with pus formation and thickening of the shaft, but sequestrum formation is rarer. Culture showed Staphylococcus aureus in 7 cases and Streptococcus haemolyticus in 1. Pain is often not severe; the temperature is moderate or low, and the lesion may become chronic before the diagnosis is made. The lesion is not visible roentgenographically until it has been present for several weeks. Treatment should consist of removal of a window in the cortex followed by the Orr treatment. Case reports are presented.

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7. Zadek, I.: Acute Osteomyelitis of the Long Bones of Adults, Arch. Surg. **37**:531 (Oct.) 1938.

Pyarthrosis Due to Bacillus Haemophilus Influenza and Corynebacterium Xerosis.—Weaver and Sherwood [8] report 2 cases of hematogenous pyarthrosis due to influenza caused by B. haemophilus. Bacteriologic studies showed the presence also of C. xerosis in 1 of their cases. From their experience and a review of the literature they conclude that the disease occurs usually in infants and only rarely in adults. If it is not associated with influenzal meningitis the prognosis as to life and function of the joint is excellent, but if such an association is present death usually occurs.

CHRONIC ARTHRITIS

Menopausal Arthralgia.—Hall [9] reports a series of 71 cases, the patients being women with arthritic symptoms beginning at an artificial menopause following castration. The patients were given estrogenic material intramuscularly in the form of estradiol benzoate (progynon B), 10,000 to 50,000 international units. Of 40 adequately treated patients suffering from arthralgia rather than true arthritis, over 70 per cent obtained almost complete relief of symptoms. Nine of 18 patients with true arthritis (atrophic, hypertrophic or mixed) were relieved of their symptoms. Hall states the belief that the rationale of estrogenic therapy is not merely restoration of ovarian hormones but the introduction of a substance which inhibits overactivity of the pituitary gland.

BACK

Spondylolisthesis.—Meyerding [10] reviews 583 cases of spondylolisthesis involving the lumbar portion of the spine. The principal complaint was backache. The average age was 40, and 70 per cent of the patients were males. The condition most frequently occurs in persons engaged in heavy labor. Its origin is traumatic or congenital. Ten per cent of the patients had no complaints referable to the back. Fusion of the involved area is recommended if conservative treatment fails.

Lumbosacral Anomalies and Pain Low in the Back.—Clarkson and Barker [11] enumerate the various anomalies which may be detected by careful roentgen examination of the lumbosacral area. The presence of these anomalies may be held accountable for pain in the lower part of the back. The technic of Williams and Wigby is advised. This

8. Weaver, J. B., and Sherwood, L.: Surgery **4**:908, 1938.

9. Hall, F. C.: New England J. Med. **219**:1015, 1938.

10. Meyerding, H. W.: Spondylolisthesis as Etiologic Factor in Backache, J. A. M. A. **111**:1971 (Nov. 26) 1938.

11. Clarkson, W., and Barker, A.: South. M. J. **31**:515, 1938.

technic consists of carefully placing the patient so that in both the lateral and the anteroposterior view the central ray will pass vertically between the fifth lumbar vertebra and the first sacral segment. A typical abdominal and pelvic pain may be caused by lower segments of the spine. The authors mention 2 cases in which there was pain in the region of the gallbladder associated with anomalies at the lumbosacral region.

Surgical Treatment of Pain Low in the Back.—Smith [12] states that it is the impression of the New York Orthopedic Group that the "pathology underlying painful backs lies far more frequently in the lumbosacral than in the sacroiliac joints. Assumption of the upright posture has placed undue strain on this area. Variations in the joints in this area, variations in the lumbosacral angle, posterior displacement of the fifth lumbar vertebra, laminal defects, spondylolisthesis, pseudosacralization and hemisacralization of the fifth lumbar vertebra and degeneration of an intervertebral disk are some of the causes of such pain. It is concluded that laminectomy and excision of the herniated disk is not always necessary, since elimination of motion in many cases is sufficient to relieve the irritation of the cauda equina. Ninety per cent of patients with pain in the lower part of the back are relieved by conservative measures. Operation is advised for 10 per cent. Five patients were operated on, the technic of Hibbs being used for spinal fusion. In the majority of cases the fifth lumbar vertebra alone was fused to the sacrum. Excellent or good results were obtained in 80 to 90 per cent. Analysis of unsatisfactory cases revealed either undetected arthritis or failure of fusion. Fasciotomy was used in 80 cases of sciatica. In many instances the pain was not relieved, but the procedure was of value in selected cases.

Compensation-Derotation Treatment of Scoliosis.—Steindler [13] states that when the compensation treatment for scoliosis was introduced twelve years ago the idea was to retrace nature's steps from the decompensated to the compensated stage on the supposition that if a natural arrest of scoliosis could occur in the state of compensation the same might be produced artificially by restoring this state. After twelve years of observation only 40 per cent of patients treated by compensation methods alone were able to maintain themselves in the compensated position without further progression of the deformity. Furthermore, it became evident that the success of fusion depends largely on the degree of spinal compensation obtained before fusion is carried out. When fusion was done before adequate compensation the position of fusion could not be maintained, but when fusion was carried out after

12. Smith, A. DeF.: Surgery **4**:13, 1938.

13. Steindler, A.: J. Bone & Joint Surg. **21**:51, 1939.

satisfactory compensation the state of compensation was maintained during the twelve years of observation. With the compensation treatment no absolute correction of any curve was accomplished. Since the spine is a column with three anteroposterior curves, lateral bending is impossible without rotation and rotation is impossible without lateral bending. Neither lateral pressure nor longitudinal traction, alone or combined, can produce correction, but derotation is an essential procedure, if not the most important prerequisite. The author states the belief that it is possible to straighten the lateral curve by derotation. This method of treatment consists of placing the patient in a Grieve chair while traction is applied or in a recumbent position on a derotating table. These pieces of apparatus were devised to enable one to mobilize the spinal column by rotation with the patient in both the sitting and the lying position. Between treatments the spine is prevented from collapsing by traction in recumbency or by a spinal brace with leg and head attachments. It would require a long time to determine the limitation of correction by derotation.

Kleinberg [14] stresses early recognition of the deformity as the most important single factor in treating this condition. He states also that persistent and continuous treatment is necessary to attain a satisfactory result. He analyzes 221 private cases of structural scoliosis. After a consideration of the etiologic factors he discusses in detail the treatment of the condition. Each type of scoliosis is considered separately. Reduction of curvature of the spine may be obtained, the author states, either by a corrective plaster of paris jacket or by application of traction on a convex frame. Illustrations of these methods are given in his paper. The former method permits the patient to be ambulatory, whereas the latter requires recumbency; but the former takes many months, the other only a few weeks. Traction on the convex frame is, in the author's experience, the simplest, quickest and most effective means of improving the scoliosis. The patient is placed in a convex frame; a Sayre halter is attached to the head of the bed and traction is applied. A pelvic girdle is put on; on each side of the girdle there is attached a band of webbing which extends to the foot of the bed. To each band a Buck's extension apparatus is attached for traction on the pelvis. With the patient recumbent, the muscles are relaxed and the deforming influence of the pull is eliminated by 5 pounds (2.3 Kg.) of traction on the head and 5 pounds on each side of the pelvis. Each day 1 to 3 pounds (0.5 to 1.3 Kg.) is added. Lateral traction may be added over the chest at the apex of the convexity. Within four to eight weeks the maximum improvement of the curvature is obtained. Additional expansion of the chest is brought about by using blow bot-

14. Kleinberg, S.: Surg., Gynec. & Obst. **67**:467, 1938

tles. When maximal improvement is obtained, a corrective celluloid corset is applied and a long period of gymnastic exercises is recommended. This part of the treatment lasts about two weeks. The author feels that when carried out uninterruptedly it yields satisfactory results in about 80 per cent of cases. Spinal fusion is advised for the remaining 20 per cent. Also, he advises spinal fusion for paralytic scoliosis and for scoliosis causing persistent and disabling backache.

NEOPLASMS

Primary Liposarcoma.—Duffey and Stewart [15] report a case of primary liposarcoma of bone arising in the femur of a 49 year old man. The tumor was discovered after a second fracture, incurred while lying in bed. Treatment consisted of high amputation, roentgen therapy and administration of Coley's toxins (erysipelas and erythrobacillus prodigiosus toxins). Later, owing to infection and recurrence of the tumor, disarticulation of the hip joint was performed. Metastasis to the lungs was controlled by irradiation and administration of toxins. A five-year follow-up showed the patient to be still well. The tumor consisted mainly of spindle cells, with irregular groups of adult fat cells and small vacuolated fat cells. The authors state the belief that the tumor was traceable to inflammatory changes in adult fat and therefore class it as a primary liposarcoma of bone.

Primary Reticulum Cell Sarcoma of Bone.—Seventeen cases of reticulum cell sarcoma of bone are reviewed by Parker and Jackson.[16] This type of growth constituted 77 per cent of primary bone tumors in patients under the age of 40 and in 35 per cent of primary bone tumors in patients under 20. It appeared most frequently in the long bones. The clinical symptoms were the same as for the other types of primary bone tumor except that the patient's general health was better than would be expected with such a severe lesion. In no other type of osseous neoplastic disease is such an extensive lesion so amenable to treatment. In the cases reported the roentgen picture was not pathognomonic. Histologically the tumor cells had round oval, indented or lobulated nuclei nearly the size of lymphocytic nuclei. The chromatin was scattered and the amount of cytoplasm considerable. Thirteen of the 17 patients were alive from one-half year to fourteen years after the onset of the disease; the other 2 died. Three patients were treated by irradiation alone; 1 died, and the 2 others, who had had neoplastic disease one to three years, were alive. Of the 9 patients treated by amputation and irradiation, 8 were alive from one-half year to fourteen years from the onset of the disease.

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15. Duffey, J., and Stewart, F. W.: Am. J. Path. **67**:467, 1938.
16. Parker, F., and Jackson, H., Jr.: Surg., Gynec. & Obst. **68**:43, 1939.

Ewing's Sarcoma.—Geschickter and Maseritz [17] studied 135 cases of Ewing's sarcoma. According to them, age, sex, duration of symptoms and systematic manifestations of the disease, while valuable adjuncts in diagnosis, are not conclusive findings. The tendency of Ewing's sarcoma to diminish rapidly under irradiation provides an important diagnostic feature, but this reaction is by no means specific; metastatic lesions and osteolytic sarcoma also respond to high voltage roentgen therapy, although not so rapidly. Roentgen diagnosis was possible in more than 70 per cent of the authors' cases, but the element of error could not be entirely eliminated, and the diagnosis necessarily rested in the last analysis on the microscopic findings. The points in differentiation between Ewing's sarcoma and similar lesions are discussed in detail and illustrated by roentgenograms. The resemblance between Ewing's sarcoma and subacute and chronic osteomyelitis still offers a serious problem. The similarity may be marked and may extend to the clinical factors of age, sex, rate, mode of rest, duration of symptoms and roentgen and physical findings. In 50 per cent of cases of Ewing's sarcoma as compared with 46 per cent of cases of osteomyelitis, the condition was found to occur in persons between 10 and 20 years of age, and in both conditions males were affected twice as often as females. Trauma played an equal role. The prognosis is grave; death occurred in 94 per cent of the cases in this series. The greatest problem is early and accurate diagnosis, for which biopsy is necessary; irradiation as a therapeutic test, however, should precede biopsy. In proved cases resection of the entire shaft, when possible, is the operation of choice except for the weight-bearing bones of the lower extremity, for which amputation is advised.

Bone Sarcoma.—Forty-seven patients with primary malignant tumors of the long bones (excluding plasma cell myeloma) were studied.[18] These included 33 with osteogenic sarcoma, 8 with Ewing's sarcoma and 2 with reticulum cell sarcoma (4 patients refused treatment and were excluded from the series). The prognosis, judging by this series of conservatively treated patients with osteogenic sarcoma, is not as bad as is generally believed. In 28 cases in which amputation was performed, 11 patients, or 39 per cent, were living without disease five years after the operation. The prognosis depends more on the amount of differentiation of the cells comprising the major portion of the tumor than on anything else. In 5 cases in which fibrous tissue predominated, amputations were performed and all the patients were well after five years. In 16 cases of the anaplastic type amputation

17. Geschickter, C. F., and Maseritz, I. H.: J. Bone & Joint Surg. **21**:26, 1939.
18. Simmonds, C. C.: Surg., Gynec. & Obst. **68**:67, 1939.

was performed, and only 1 patient was well after five years. Of the patients with Ewing's sarcoma, 4 were treated by irradiation and 4 by operation. All died.

NEUROLOGIC LESIONS

Pressure on the Brachial Plexus.—Naffziger and Grant [19] discuss 18 cases of the so-called scalenus syndrome, i. e., the signs and symptoms of cervical rib pressure on the brachial plexus without the presence of cervical ribs. Pain was the most common symptom, radiating into the hand in cases of severe involvement. Weakness was found only in cases of long-standing involvement. Symptoms could be brought on or increased in all cases by tensing the anterior scalenus muscle on the affected side. There was consistent tenderness over the insertion of the scalenus muscle on the first rib. One-half the patients showed evidence of disturbance of the sympathetic nervous system. The condition is believed to be due to anatomic and developmental factors that produced an abnormal position of the shoulder girdle in relation to the thoracic cage; among these are an embryologically "post-fixed" brachial plexus, injury, occupational strain and poor posture. Myotomy of the scalenus anticus muscle is required when postural treatment fails to relieve symptoms. In the authors' series the operative results were excellent, though recovery sometimes took several months.

FOOT

Bruce and Walmsley [20] state the opinion that the current clinical teaching on the arches of the foot is confusing and unsatisfactory. They have conducted a study of the architecture of the foot from the standpoint of development. Their observations satisfy them as to the presence of a longitudinal arch, but they can find no support for the theory of the presence of a transverse arch at the heads of the metatarsal bones. They state the opinion that pain in the metatarsal region is commonly due to splaying of the metatarsal heads with consequent strain on the transverse metartarsal ligaments. Such splaying may be due to decreased weight bearing on the head of the first metatarsal bone from congenital or other causes. The authors derive additional evidence for overstrain as a factor from the fact that dorsiflexion of the toes is often observed. This they conclude to be due to the unapposed contraction of the long and short flexor and extensor tendons in consequence of atrophy of the lumbricalis-interosseus system. For treatment they consider a metatarsal pad irrational. Relief depends on restoring the balance between the metatarsal bones and their load. The most important step is restoration of the functional activity to the lumbricalis-interosseus system,

19. Naffziger, H. C., and Grant, W. T.: Surg., Gynec. & Obst. **67**:722, 1938.

20. Bruce, J., and Walmsley, R.: Lancet **2**:656, 1938.

and preliminary correction of a dorsiflexion deformity of the toes is indicated. This is affected by tenotomy of the extensor tendons on the dorsum of the foot and of the contracted flexor tendons opposite the interphalangeal joints, followed by corrective fixation in plaster for several weeks.

[ED. NOTE: This is an interesting and helpful study. Most orthopedic surgeons consider tenotomy of the extensor tendons of the toes a procedure likely to produce further deformity. Manipulation and exercises will usually overcome contracture.]

Osteochondritis of the Tarsal Navicular Bone.—Brailsford [21] distinguishes between osteochondritis in Köhler's disease, which occurs in the tarsal navicular bone in children between the ages of 2½ and 10 years, and osteochondritis of the tarsal navicular bone in adults. The characteristic lesion of the latter in the 9 cases reported occurred only in women. The process consists of an oblique splitting of the navicular bone and separation of the two fragments. The inner fragment gradually glides over the head of the astragalus to the medial side, and the outer fragment overrides the dorsal surface of the second and third cuneiform bones. In the later stages severe osteoarthritic changes develop in the normal midtarsal joint. These changes may be bilateral. In all 9 of Brailsford's cases there was bilateral involvement though the degree was not the same on both sides in every instance. The ages of the patients varied from 22 to 59. No conditions presenting similar roentgen appearances were observed by this author in men.

[ED. NOTE.—Similar changes have been seen by several of the editors in roentenograms of the feet in cases of osteoarthritis. Further study will determine whether this should be considered a separate entity or part of osteoarthritis.]

HAND

Purposeful Splinting of Injuries of the Hand.—Koch and Mason [22] emphasize the importance of rest in the treatment of injured tissues to secure muscular relaxation in cases of tendon injury and to bring constant tension on contractile scar tissue. They discuss application of splints for these purposes and illustrate the use of such splints by photographs and diagrams.

[ED. NOTE: This is an excellent article describing many unique and useful appliances.]

Swollen Atrophic Hand.—Oppenheimer [23] gives the clinical and roentgen findings in the cases of 14 patients in whom a peculiar swell-

21. Brailsford, J. M.: J. Bone & Joint Surg. **21**:111, 1939.

22. Koch, S. L., and Mason, M. L.: Surg., Gynec. & Obst. **68**:1, 1939.

23. Oppenheimer, A.: Surg., Gynec. & Obst. **67**:446, 1939.

ing accompanied atrophy of the skin, the interosseus muscles and the bones of the hand. It was found to be correlated with unilateral bony constriction of the intervertebral foramens in the upper part of the cervical region of the spine on the side of the affected hand. The clinical syndrome was independent of the pathologic process which produced this constriction. In 6 of the 7 patients treated, cure was obtained by ultrashort wave therapy over the cervical portion of the spine. Atrophy of the bones was found to be correlated with atrophy of the skin but was independent of atrophy of the muscles. The author concludes that the development of well marked trophic lesions in an extremity affected for many years by rheumatic or arthritic pains seems to indicate that the pain may be due to radicular neuritis caused by chronic disease of the spinal column.

SHOULDER

Subacromial Bursitis.—Rubert [24] describes a clinical, roentgen and statistical study of subacromial bursitis, with a review of 288 cases from the clinic of Arthur Steindler. This condition may be due to local trauma, direct or indirect, or to inflammation. In one group of cases it may be ascribed to general constitutional changes, such as arthritis, or to metabolic and nutritional changes. The pathologic process may be bursal and peribursal. The bursal changes consist of thickening of the walls, thickening of the synovial villi, exudation of fluid and adhesions. The peribursal changes are deposits of lime in the subjacent tendons due to injury or inflammation, with attempt at repair hindered by the poor blood supply of the region. Roentgenograms in several planes are important to rule out other possibilities, such as fracture and tumor, and to reveal the presence or absence of calcification. Codman's classification of subacromial bursitis is useful: 1. Acute spasmodic bursitis, with local evidence or inflammation, pain, tenderness and secondary muscle spasm. It may or may not show calcareous deposits. 2. Subacute adhesive bursitis, a result of progression of the acute spasmodic type. There is limitation of abduction and rotation but no severe pain. 3. Chronic nonadhesive bursitis, a further stage, with the adhesions gone but with residual roughening of the bursal walls. There is pain on motion in certain arcs as the roughened area passes beneath the acromion. 4. Bursitis due to complete tendon rupture.

Two hundred and eighty-eight cases are analyzed. The greatest age incidence was between 40 and 70. Five per cent of the patients showed local evidence of arthritis in the shoulder, differentiated from bursitis by the complete loss of motion and by the more obtuse angle between the scapula and the humeral shaft. The midpoint of arrest of

24. Rubert, S. R.: Subacromial Bursitis: A Clinical, Roentgenographic and Statistical Study, Arch. Surg. **37**:619 (Oct.) 1938.

the shoulder due to arthritis is at 25 degrees of flexion and forward motion, so that when the arm is at the side the vertebral border of the scapula is no longer straight down but points medially in the midline. Injuries to the biceps tendon are differentiated by the limitation of forward and backward motion. In cases of acute involvement, rest in abduction and external rotation, with use of heat and opiates, followed by mild passive motion as soon as possible, is indicated. Irrigation of the bursa with about 60 cc. of procaine hydrochloride solution is a good form of therapy. Manipulation, always gentle, is practiced to free adhesions if conservative treatment fails. Operative treatment for relief of tension and removal of calcifications and for tendon repair if the tendon is torn is confined to cases of acute involvement.

Periarticular Calcification of the Shoulder.—Mallet-Guy and Frieh [25] review the subject of painful shoulders with calcification, restating Codman's observations and theories. The poor blood supply of the supraspinatus tendon plus the constant motion of the joint prevents proper scar formation and results in the deposit of calcium in the mass of necrotic fibers. Spontaneous perforation of the calcified deposit into the bursa is the rule, and this represents the process of the lesion. The particles are gradually absorbed by the fibrinous fluid secreted by the bursa, and the bursa tends to return to normal save for adhesions and thickened villi. If perforation does not occur the reaction in the neighboring bursa may gradually subside, but there is danger of relapse and of chronic functional disability. The clinical features are variable. The roentgenogram may reveal calcification in both shoulders, one shoulder being symptomless. Treatment should be dominated by the idea that spontaneous healing is the rule. Immobilization in bed with the arm in abduction with periods of passive motion to prevent adhesions may be tried. Diathermy, infra-red rays and irradiation therapy may be used. Infiltrations of a local anesthetic combined with aspiration of the contents of the bursa is of proved value. Excision of the bursa should be a last resort.

MISCELLANEOUS

Plastic Surgery for Children.—Straith and De Kleine [26] gave numerous examples of the psychologic effects of deformity in childhood, i. e., inferiority, shame, modifications of self expression and antisocial tendencies. The surgical care of such deformities is discussed, but the main emphasis is placed on the medicopsychologic aspects. The conclusions are: 1. The importance of many deformities lies in the severe mental reactions and alterations of personality which result. 2. In the presence

25. Mallet-Guy, P., and Frieh, P.: Rev. d'orthop. **26**:20, 1939.

26. Straith, C. L., and De Kleine, E. H.: Plastic Surgery in Children: Medical and Psychologic Aspects of Deformity, J. A. M. A. **111**:2364 (Dec. 24) 1938.

of deformity the most important single factor is surgical restoration to normal at the earliest possible date. 3. Whenever possible deformities in children should be corrected before school age.

[ED. NOTE.—Most of the examples used in this article did not fall strictly under the head of orthopedic surgery, being cases of cleft palate, deformities of the nose and similar conditions, but the general conclusions concern the orthopedic as well as the plastic surgeon.]

OPERATIONS ON BONES AND JOINTS

Surgical Repair of the Long Disabled Hand.—Young [27] reviews known principles in the surgical repair of hands long disabled owing to infection or to trauma in skin, subcutaneous tissue, tendons, tendon sheaths or joints. He stresses asepsis, adequate preoperative care of the skin, proper placing of cutaneous incisions and accurate hemostasis. He states that he has never had a recurrence of a surgically treated Dupuytren contracture after complete removal of the fibrous aponeurosis, complete hemostasis, grafting of skin flaps and immobilization of the fingers in extension during healing.

Chronic Synovitis Treated by Synovectomy.—Inge [28] reviewed 86 cases of synovectomy of the knee joints followed from one-half to five and one-half years. Synovectomy for specific lesions, such as tuberculosis, echinococcic disease, osteitis of the tibia and hemangioma, failed in all cases. The conditions in the remaining 77 cases were divided into rheumatoid arthritis, osteoarthritis and chronic synovitis (the latter including 9 cases of trauma and 6 of osteochondromatosis). The conclusions drawn were: 1. In properly selected cases of nonspecific proliferative synovitis, synovectomy offers a 95 per cent chance of improvement and a 60 per cent chance of restoration of a practically normal joint. 2. Patients with osteoarthritis with secondary synovial hypertrophy have a 90 per cent chance for improvement. 3. In this series, patients with rheumatoid arthritis were relieved in only 50 per cent of cases, and the knees of some were made worse. 4. Failures were due to improper selection of cases. The rules for the proper selection of cases suggested by Swett and Jones in 1923 are still valid.

[ED. NOTE: Synovectomy carefully performed with attention to hemostasis and with early motion in the joint is a useful procedure for quiescent arthritis. When the arthritis is active, support of the joint and roentgentherapy are far safer.]

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27. Young, F.: Surg., Gynec. & Obst. **67**:273, 1938.

28. Inge, G. A. L.: Eighty-Six Cases of Chronic Synovitis of the Knee Joint Treated by Synovectomy, J. A. M. A. **111**:2451 (Dec. 31) 1938.

Hoke Operation for Flatfoot.—L'Episcopo and Sabatelle [29] report on a series of 16 patients on whom operation for flatfoot was performed. The procedure was essentially that devised by Hoke in 1931 except that an attempt to fuse only the first cuneiform and navicular bones was made and that in some cases the heel cord was lengthened. The average age of the patients was 13 years; the youngest was 7 and the oldest 19. The operation was performed only on patients with flaccid flat feet associated with pain or fatigue or both and in whom the symptoms were static. No cases of arthritis were included. The follow-up period varied from eight months to three years. The results were good in 68.7 per cent and fair in 31.3 per cent of cases. The authors felt that the operation was definitely indicated in a well selected group of children with flaccid flat feet. It seems that bony union is not essential for good results. Some patients were definitely relieved in spite of fibrous union.

Restoration of Muscle Balance in the Treatment of Obstetric Paralysis.—L'Episcopo [30] finds that the shoulder joint in obstetric paralysis of the upper part of the arm is not adducted; there are slight posterior dislocation of the head of the humerus and torsion of the upper part of the humerus. Because there is marked muscular imbalance with a tendency of the pectoralis major, teres major, subscapularis and latissimus dorsi muscles to shorten, he has devised a method of transplanting muscles to secure better muscular balance. Two incisions are made, along the anterior and along the posterior margin of the deltoid muscle. The teres major and the latissimus dorsi muscle are freed from the medial aspect of the humerus. The contracted anterior articular capsule is then cut to permit outward rotation of the humerus. The teres major and latissimus dorsi muscles are brought about the under side of the humerus and fixed to an osteoperiosteal flap on the lateral side of the humerus. The author has performed the operation on 15 patients with obstetric paralysis and on 1 patient with spastic paralysis. The 15 patients with obstetric paralysis all showed marked functional improvement.

FRACTURES AND DISLOCATIONS

Fracture-Dislocation of the Spine.—Of 259 patients with injury to the spine admitted to the hospital over a five year period, 80 had symptoms referable to the spinal cord or to the nerve roots. The group with injuries to the cord were discussed by Coleman and Meredith,[31]

29. L'Episcopo, J. B., and Sabatelle, P. E.: J. Bone & Joint Surg. **21**:92, 1939.

30. L'Episcopo, J. B.: New York State J. Med. **39**:357, 1939.

31. Coleman, C. C., and Meredith, J. M.: Treatment of Fracture-Dislocation of the Spine Associated with Cord Injury, J. A. M. A. **111**:2168 (Dec. 10) 1938.

the following conclusions being reached: 1. Laminectomy is indicated only in cases in which the cord is compressed but not destroyed. 2. If lumbar puncture shows no block, operation is not indicated. If block is present, operation is indicated only if it seems that the cord possessed some ability for repair. 3. If lesions of the cord produce immediate complete interruption, operation is futile. 4. Reduction of cervical dislocations does not improve the prognosis of injury of the cord but sometimes helps root symptoms. 5. Severe but incomplete lesion of the cervical segment of the cord should be treated with traction for twenty-four hours; if no improvement occurs, laminectomy should be done. 6. For severe incomplete dorsal lesions immediate laminectomy is advisable. 7. Prompt laminectomy is indicated for complete lesions of the cauda equina.

Recurrent Dislocation of the Shoulder.—Twenty-five cases of recurrent dislocation of the shoulder in which operation was performed by a number of different surgeons according to the Nicola technic were collected by Horwitz and Davidson.[32] Twenty cases have been used as the basis of this study. The postoperative period varied from six months to eight years at the time this study was made. There were 17 successful results and 3 recurrences. In 1 of the cases in which dislocation recurred there was a violent injury, and at operation a rupture was found of the spanning portion of the tendon in the joint. In a second case of recurrence the shoulder felt stronger and the dislocations were less frequent after the operation. In the third case of recurrence following the Nicola suspension there was a hiatus in the deltoid muscle due to stripping of the attachment of this muscle at the time of operation. There was abnormal mobility of this muscle at the time of operation. There was abnormal mobility of the humeral head, indicating excess length of the tendon due either to stretching or to improper attachment of the tendon in the osseous tunnel. Also, the disturbance in growth caused by drilling across the epiphysial plate in a child of 12 years may have disturbed the mechanics of the new intra-articular ligament.

Transcondylar Fractures in Childhood.—Dunlop[33] discusses the treatment of a type of fracture which involves the lower end of the humerus in young children. It is most prevalent between the ages of 5 and 12 years. The fracture passes across the broad distal end of the humerus and through the thick portion of the bone known as the olecranon and the coronoid fossa. The distal fragment remains in one piece. The lesion has been called by some authors an epiphysial separation. However, there is no epiphysial line at this level of the bone.

32. Horwitz, M. T., and Davidson, A. J.: Surgery **4**:74, 1938.
33. Dunlop, J.: J. Bone & Joint Surg. **21**:59, 1939.

although there is one distal to the line of fracture. Traction by adhesive tape is applied to the arm up to the elbow joint; treatment is continued by gradual straightening of the arm and attachment of weight to the traction apparatus, which is similar to a Buck's extension applied to the side of the bed with a pulley. Elevation of the side of the bed toward the traction or the attachment of a sheet about the body of the patient may be necessary to prevent him from being pulled out of bed. One-half hour after the application of traction roentgenograms should be taken to determine the amount of weight required and the necessity for a counterweight with a sling over the upper part of the arm. An additional roentgenogram should be taken in three to four hours to determine whether there should be an increase in the amount of weight used or a change of the angle of pull. When the roentgenogram reveals sufficient callus, traction is removed and a posterior plaster is applied. A sling is given with the elbow flexed at right angles. The child is then allowed to go home with the arm in the sling. In three to four weeks the splint is removed. The arm is tied to the neck with a cravat sling, and motion is started. It is unwise to force straightening of the elbow. A normal elbow should result in three or four months.

Neurologic Lesions in Recent Fractures of the Lower End of the Humerus.—Sorrel and Sorrel-Dejerine [34] review 252 cases of recent fracture of the lower end of the humerus, in 21 of which the condition was complicated by injury to one or more nerves. There were 207 supracondylar fractures, 23 fractures of the internal epicondyle and 22 fractures of the external condyle. Of the 207 supracondylar fractures, there were 23 of the internal epicondyle and 22 of the external condyle. Of the 207 supracondylar fractures, there were 23 of the flexion type of fracture, and in these 23 the ulnar nerve was involved 7 times, an incidence of 30 per cent. The mechanism of the neural injury is described as follows: the nerve, being flexed in the groove of the olecranon, is pulled forward with the distal fragment of the humerus. This produces angulation of the nerve on the proximal fragment, resulting in paralysis. In none of these 7 cases of ulnar paralysis was the nerve actually torn. In 4 cases the paralysis was noticed only after removal of the plaster; at operation the nerve was found to be pressed on by a spur from the proximal fragment and was not involved in callus. In 1 instance the nerve was crushed between the fragments. On the average, recovery of the nerve begins from eight days to three weeks after operation, with complete recovery in six to eight months. If reduction of the fracture is satisfactory, it is safe to wait up to fifteen days for signs of recovery of the nerve before operation is undertaken. If the reduction is not satisfactory, however,

34. Sorrel, E., and Sorrel-Dejerine (Mme.): Rev. d'orthop. **25**:609, 1938.

operation should be done early. Associated with the 184 supracondylar fractures of the extension type "there were 4 instances of radial paralysis (2.1 per cent), 4 of median paralysis (2.1 per cent) and 1 of combined median and ulnar paralysis." The mechanism was stretching of the median and radial nerves over the proximal fragment by the backward displacement of the distal fragment, but the nerves were protected in most instances by the cushion of the brachialis muscle so that they were infrequently injured. For paralysis of the radial nerve 3 operations were done. In 1 case the nerve was found severed; in the other 2 it was only pressed on and flattened. In the fourth case the paralysis disappeared soon after a good closed reduction. The authors advise operation at the end of fifteen days if there is no improvement. Paralysis of the median nerve was accompanied in each case by signs of vascular compression, with absence of the radial pulse signs of an impending ischemic contracture. In 3 of these cases immediate operation was done, which revealed marked compression of the vascular bundle and the median nerve, caused by protrusion of the proximal fragment through the torn brachialis muscle. In the fourth case a Kirschner wire was placed through the olecranon, producing an excellent reduction, and all symptoms rapidly disappeared. In the 1 case of paralysis of the median and the ulnar nerve together the weakness was noticed forty days after a good reduction by an open operation. The paralysis disappeared one month later. There were 25 fractures of the medial epicondyle with 4 lesions of the ulnar nerve, an incidence of 17.4 per cent. Three of the fractures were accompanied by dislocation of the elbow. In 2 of the dislocations the epicondyle and the nerve were caught in the joint after reduction of the dislocation. Operation should always be done in such circumstances. In 3 of the patients full return of function required six to seven months; 1 patient could not be followed. There were 22 cases of fracture of the external condyle with 1 instance of paralysis of the ulnar nerve. In this case a large fragment was torn off, accompanied by a complete lateral dislocation of the radius and ulnar nerve. Two and one-half months after the operation recovery was complete. In the remaining case the ulna was transfixed by a Kirschner wire. There were no immediate symptoms, and the paralysis was discovered only after removal of the plaster. Two months later operation was done and the nerve was freed from adhesions. Complete recovery required fourteen months.

Late Rupture of the Extensor Pollicis Longus Tendon After Colles' Fracture.—Blount [35] reports 2 cases of rupture of the tendon of the extensor pollicis longus muscle after Colles' fracture. One patient was a 44 year old janitor in whom rupture of the tendon occurred two

35. Blount, W. P.: Wisconsin M. J. **37**:912, 1938.

months after the fracture. The other patient was a seamstress 56 years old in whom rupture of the tendon occurred three weeks after injury. Rupture of the tendon occurs from injury to the mesotendon and interference with the blood supply as a result of the fracture. Pain is frequently absent, the patient becoming aware of the injury when there is inability to extend the distal phalanx of the thumb. Rupture of the tendon occurs several weeks to several months after the patient has returned to work. Tendon suture is easily performed if treatment is sought early. In cases of neglect a tendon graft may be required. This is a rare complication of Colles' fracture. A review of the literature is given.

Fractures of the Neck of the Femur.—Putti [36] discusses in detail the types of fracture of the hip but limits his discussion of therapy to intracapsular lesions. He states the belief that a lag screw supplies a positive opposing factor in immobilizing these fractures, whereas a Smith-Petersen nail acts only as a passive internal splint. All the operative stages utilized in inserting the steel lag screw are well described and illustrated. A portable roentgen unit with two tubes on one stand is used, so that anterior, posterior and lateral roentgenograms may be taken repeatedly as desired without shifting the tube or changing the position of the patient on the traction table. A 4-inch (10 cm.) lateral incision is used. The following statistics are given: Cases of fractured hips treated in the Institute Rizzoli up to 1937 included 698 cases in which treatment by reduction and plaster was used. In 529, or 75.7 per cent, the fractures are reported as healed. Though the Smith-Petersen nail has been used, this series is not reported. Of 34 fractures for which the lag screw was used, 9 were subcapital fractures, 23 were transcervical fractures and 2 were fractures through the base of the neck. The screw was introduced in 31 cases between the fifth and the thirtieth day, in 1 case after five months and in 1 after seven months. The preliminary reduction was accomplished by cutaneous traction with the patient in bed, the extremity being abducted and internally rotated with slight flexion. The results are based on 32 cases, the patients in 2 being still under treatment. Four patients, or 12.1 per cent, died. Excluding the 4 who died and 3 who did not return, the results are classified as follows: in 17 cases, or 68 per cent, excellent (bony union); in 5 cases, or 20 per cent, good (stable joints), and in 3 cases, or 12 per cent, poor. Roentgenograms are shown in 19 cases, in 15 instances showing obvious osseous union and excellent anatomic position. Incidentally, after fixation with the lag screw a plaster spica was applied; this was "bivalved" after the first month to allow physical therapy and was removed after the second month. A brief report was also made of

36. Putti, V.: Chir. d. org. di movimento **23**:399, 1938.

21 cases of nonunion, the earliest two and one-half months and the latest twenty-one months after operation, treated by intertrochanteric osteotomy. One patient died; in the case of another abduction was inadequate. All of the remaining 19, however, had satisfactory results, 3 roentgenograms shown proving bony union. Satisfactory results were obtained in treatment of pseudarthrosis.

[ED. NOTE.—The article is excellent, but it is not a convincing argument for the lag screw. In the first place, immobilization required accessory plaster spicas. In the second place, the incidence of union is not high as compared to recent results in America, where the Smith-Petersen nail has been used.]

Treatment of Fractures of the Ankle.—In this paper Campbell [37] describes in detail the various types of fractures of the ankle. He divides them into two main classes, major fractures and minor fractures. In the author's opinion, treatment of the former by means of a skin-tight walking plaster cast can hardly be improved on. Minor fractures, he states, are often given treatment neither necessary nor advantageous. Minor fractures are those in which only one side of the joint is involved. Such fractures are considered invariably stable. Involvement of both sides does not necessitate a fracture through bone on each side, a tear of the lateral ligament combined with a fracture on the other side being sufficient to place the lesion in the group of major fractures. In the treatment of minor fractures the author has adopted Leriche's method of local anesthesia by infiltration with procaine hydrochloride. The pain is abolished, and the patient is allowed to walk home without support. He is seen the next day, as occasionally a second infiltration is required. He is encouraged to resume his normal activity. Roentgenograms are taken from time to time until bony union occurs. The author reports in detail a series of 18 cases in which treatment was conservative; in none of these has displacement or nonunion been found to result.

RESEARCH

Ox Fascia Grafts in Tendon Defects.—This is a study [38] to determine whether dead fascia used to fill tendon defects will or will not act as a foreign body and whether or not absorption occurs. Previous studies by Nageotte and Sencert have shown that the dead cells of a graft are removed by wandering cells from the host, after which fibroblasts from the host grow into the preexisting connective tissue framework of the graft and repopulate it with living cells. In 25 dogs a

37. Campbell, W. G.: Lancet **2**:872, 1938.

38. Weinberg, E. D.: Dead (Ox) Fascia Grafts in Tendon Defects: An Experimental Study, Arch. Surg. **37**:570 (Oct.) 1938.

section of the tendon in the foreleg was removed and ox fascia preserved in 70 per cent alcohol was sutured to the stump ends. The dogs were killed at intervals varying from eleven to two hundred and eighty-five days, and the tendons were studied. It was found that the ends of the graft became frayed out and edematous and were invaded by an ingrowth of young fibroblasts. These fibroblasts later worked their way into the interior of the graft, so that after forty-two days little evidence of the dead graft as such remained. There was no foreign body giant cell reaction around the silk sutures. The preserved fascia was well tolerated, and in time there was such a complete substitution that it was difficult to tell that the graft had ever been dead.

Use of Hydrochloric Acid in Delayed Calcification of Fractures.—Cornell and his associates [39] report the clinical and roentgen observations in 5 cases of fractured bones in which excessive atrophy of bone and delayed calcifications were found about the site of fracture. Observations suggested that the osseous atrophy was the result of some metabolic or constitutional disturbance affecting the intestinal absorption and subsequent utilization of calcium salts and was thus responsible for the delayed calcification. The evidence indicated that the disturbance was due to decrease or absence of hydrochloric acid in the stomach. Calcium salts are soluble in acids and relatively insoluble in an alkaline medium. Intestinal acidity is due to hydrochloric acid in the stomach, to the fatty acid formed during digestion and to lactic acid fermentation. Vitamin D also is associated with the production of intestinal acidity. Telfer's experiment led him to state that absorption of calcium is initially dependent on the free hydrochloric acid in the stomach. The use of hydrochloric acid without the proper calcium intake may be harmful since hydrochloric acid, besides furthering the utilization of calcium, increases excretion of this substance. Analysis of the gastric contents was carried out in 20 cases of fractures, and in 12 of these the findings were normal and normal healing occurred. In 8 cases gastric acidity was either absent or low and was associated with a diminished volume of gastric content. In these 8 cases healing did not occur with the usual method of treatment. The authors conclude that the addition of hydrochloric acid (4 to 8 cc. of a 10 per cent dilution three times a day) to a diet high in calcium and vitamins increases the absorption of calcium and furthers the calcification of bone.

Bone Regeneration.—Levander [40] has endeavored to find a reason for the metaplastic theory of bone formation, i. e., the transformation of connective tissue into bone tissue. He has studied the mode of

39. Cornell, L. W.; Bernheim, A. R., and Person, E. C.: J. Bone & Joint. Surg. **21**:40, 1939.

40. Levander, H.: Surg., Gynec. & Obst. **67**:705, 1938.

origin of new bone after transplanting into soft parts hard bone tissue stripped of periosteum. This new bone seemed to be formed from mesenchymal tissue about the graft but not necessarily in contact with it. Alcoholic extracts of bone tissue were injected into soft structures, and in 22 per cent of instances cartilage or bone was formed. After control injections of alcohol alone no bone was formed. The author concludes that bone regeneration takes place as the result of some specific bone-forming substance activating the nonspecific mesenchymal tissue.

Calcification of Hyaline Cartilage.—Falconer [41] examined costal, tracheal and bronchial cartilage taken from old persons with reference to the occurrence of calcium. In only 41 of 200 cases was the cartilage macroscopically free from calcium, but in many of these cases microscopic calcium deposits were observed. There are three different ways in which calcium settles in the cartilage: (1) as a diffuse distribution of small kernels; (2) like a capsule around the dying cartilage, and (3) in the form of strands which traverse the interstices between the endoplasmic areas in the exoplasm.

Roentgen Appearance of the Ligaments of the Knee Joint.—Lindblom [42] has been able to demonstrate the ligaments of the knee joint by the injection of perabrodil (skiodan), a water-soluble radiopaque substance, into the knee joint. If there was effusion within the joint preliminary aspiration was done. About 15 cc. of 4 parts of perabrodil and 1 part of 0.5 per cent procaine hydrochloride was injected. Stereoscopic lateral roentgenograms were taken with the knee flexed 90 degrees, and anteroposterior roentgenograms, with the knee flexed 50 degrees. Lesions of the cruciate ligaments and of the tibial collateral ligament could be demonstrated.

Roentgen Diagnosis of Destructive Lesions of the Knee Joint.—More than 190 defects of varying size and location were produced in the bones about the knee joint by Lachmann.[43] These involved the cortex and the spongiosa separately and in combination. The results revealed that not all osseous defects are visible on the roentgenogram in either frontal or profile views unless they are of minimum size. The dimensions necessary for visibility vary with the location of the defect. Conoid excavations involving only the spongy structure require a diameter of from 0.5 to 1.7 cm. at their base and a depth of from 0.5 to 0.9 cm. Disklike cortical defects must have a diameter of from 0.5 to 2 cm. in order to be seen, the factors determining visibility of a defect

41. Falconer, B.: Calcification of the Hyaline Cartilage in Man, Arch. Path. **26**:942 (Nov.) 1938.

42. Lindblom, K.: Acta radiol. **19**:582, 1938.

43. Lachmann, E.: Radiology **3**:521, 1938.

are: (1) direction of its longest axis in relation to the central x-ray beam; (2) the diameter of the transradiate forms superimposed over the defect; (3) the relative amounts of cortical and spongy matter in the overlying bone; (4) the distance of the defect from the tube and the film; (5) the character of the border of the excavation; (6) the content of the defect, and (7) the state of calcification of the surrounding bone. In the light of these results the limitations of roentgen diagnosis in deep infections frequently involving the knee joint are pointed out. For example, special attention is called to the fact that a normal roentgenogram does not exclude the possibility of tuberculosis of the knee joint and that the roentgenogram gives a picture of the stage, prognosis and progress of the disease only with certain reservations, none of the classic roentgen signs of tuberculosis in itself being typical of this infection. In regard to osteogenic sarcoma, it is pointed out that this infection may be present with normal findings and that no roentgen sign of osteogenic sarcoma is absolutely characteristic. In regard to osteochondritis dissecans, it is pointed out that the first stage of this condition escapes roentgen diagnosis. Later phases of the disease may be visible, but this depends on the width and position of the radiolucent ring around the necrotic bone fragment. In this study, for example, when the line of demarcation did not exceed 1 mm. the front view was normal and the side view showed only a faint interrupted outline of parts of the fissure surrounding the fragment.

News and Comment

International Congress of European Society of Structive Surgery.—The fourth international congress under the auspices of the European Society of Structive Surgery will be held in Paris, October 5 to 7. The honorary president of the congress is Prof. P. Sebileau, member of the Academy of Medicine of Paris, and the president is Dr. L. Dufourmentel. The following two subjects will be discussed: (1) treatment of destructions and deformities resulting from scar retraction of the eyelid; (2) treatment of deformities of the jaw. There will also be presentation of other communications on subjects within the scope of reconstructive and plastic surgery, as well as demonstrations of plastic operations. Further information concerning the congress, including the rates which are available for the voyage and for the stay in Paris, may be obtained from the secretariat of the congress, Maison de Chirurgie, 9 Rue de Turin, Paris 8e, France.

Congrès Français d'Urologie.—The thirty-ninth Congrès Français d'Urologie will be held in Paris from October 9 to 13. The subject for discussion will be the results of nephrectomy for cancer of the kidney in adults. Further information may be obtained from the general secretary of the Association Française d'Urologie, Dr. Louis Michon, 40 Rue Barbet-de-Jouy, Paris, 7e, France.